MARCH 1957

Agricultural Engineering

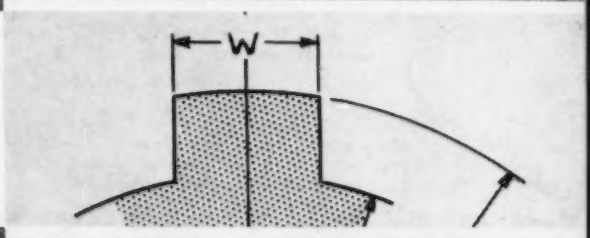
The Journal of the American Society of Agricultural Engineers

Needed: A Substitute for a Team of Mules | 162

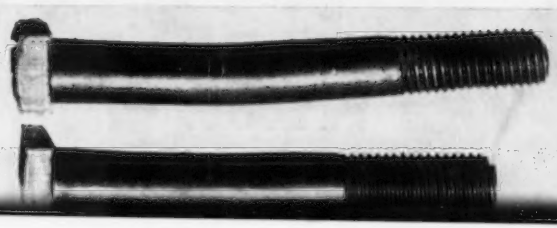
Aids for Determining Runoff Probability | 164

Predicting Pressure Drops in Pneumatic Conveying of Grains | 168

Properties of Straight-Sided Splines | 172



Bolted Plywood Gussets | 174



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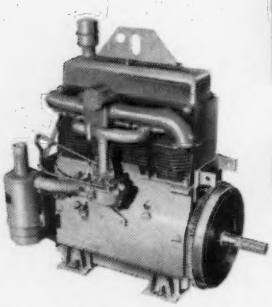
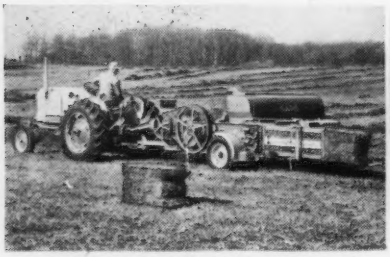
Model 160, twine or wire. Available with V-type engine shown on baler, powerful Case engine shown below or PTO drive.



Packs Away a Lot of Tonnage

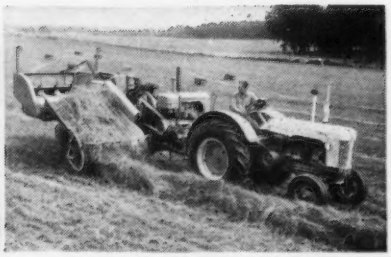
New More Powerful Air-Cooled Engine

Double-plunger action of Case 160 and 140 balers puts a "one-two punch" into slicing and compressing, pushes out amazing tonnage of compact, well-formed bales. Case 4-cylinder axial-flow air-cooled engine provides higher peak capacity, long life, low upkeep. Wire models make only one tie per wire, tuck ends down, leave no wire clippings, no slack. Twine models have super-simple, sure-tie knotters with exclusive offset bill-hook. Owners report a thousand and more bales without a miss. Unit-frame mounting of knotter or wire twister holds parts in precise alignment, protected from warping strain in rough going. Big, closed-drum pick-up adjusts from tractor seat to save hay, skip trash. Gentle handling saves protein-rich leaves. Big tonnage saves time that means money.



New 133 twine baler has 26-inch stroke, six hay dogs, for firm 14x18 bales in fewer strokes. Same sure-tie knotter as larger models. Choice of PTO or air-cooled engine.

Case 140 big-tonnage baler makes 14x18 sliced bales of uniform, yet widely variable length. Twine or wire tie. Case air-cooled engine, V-type engine, or PTO drive.



New heavy-duty NAP-3 baler makes compact 17x22 bales. Only one tie in each of three wires; ends are tucked down, no clippings. Case *water-cooled* engine. Has starter and lights.

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Let us send you pictorial catalogs on machines you check below, also others you may write in margin. Address J. I. Case Co., Dept. C-617, Racine, Wis.

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Agricultural Engineering

Established 1920

CONTENTS • MARCH, 1957 • Vol. 38, No. 3

Editorial 161

Needed: A Substitute for a Team of Mules 162
G. B. Gunlogson

Aids for Determining Runoff Probability 164
Roy G. Andrews

Predicting Pressure Drop in Pneumatic Conveying of Grains 168
J. W. Crane and W. M. Carleton

Properties of Straight-Sided Spline Section 172
R. Bruce Hopkins

Bolted Plywood Gussets 174
L. M. Staley and L. W. Neubauer

ASAE Committee Reports 177

News Section 180

Technical Paper Abstracts 181

Readers' Forum 186

New Products 188

Manufacturers' Literature 193

Index to Advertisers 206

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Cotton Leader Retires

Charles A. Bennett (ASAE Fellow) retired February 28 after more than 30 years of service with the U.S. Department of Agriculture. "Uncle Charlie" as he is affectionately known by friends in the cotton industry, is recognized as one of the cotton experts of the world and was awarded the Cyrus Hall McCormick Medal by ASAE in 1945 and the USDA Distinguished Service Award in 1952. He is called the father of the modern and improved ginning, cleaning and drying methods for cotton. At the time of his retirement he was principal agricultural engineer for cotton ginning investigations.

C. A. BENNETT

Mr. Bennett was born in 1889 at Tecumseh, Nebr. In 1911 he graduated from the University of Nebraska with a B.S. degree in mechanical engineering. Immediately following graduation he became a draftsman for the Omaha Light & Power Co. Until 1926, when he joined the USDA to handle a research project for the development of seed cotton drying methods and cotton gin equipment, he held positions with the Omaha Machine Works, Anderson and Bennett, U. S. Navy Yard in Puget Sound, and American Liquid Meter Co.

From 1930 to 1951 he was engineer-in-charge of the Cotton Ginning Research Laboratory in Stoneville, Miss., and later became regional engineer for four cotton ginning research laboratories and for cooperative work at Shafter, Calif., and other USDA cotton field stations.

He developed a drying apparatus and made numerous improvements in methods and equipment for handling, drying, cleaning, storing, extracting, ginning, and packaging of cotton.

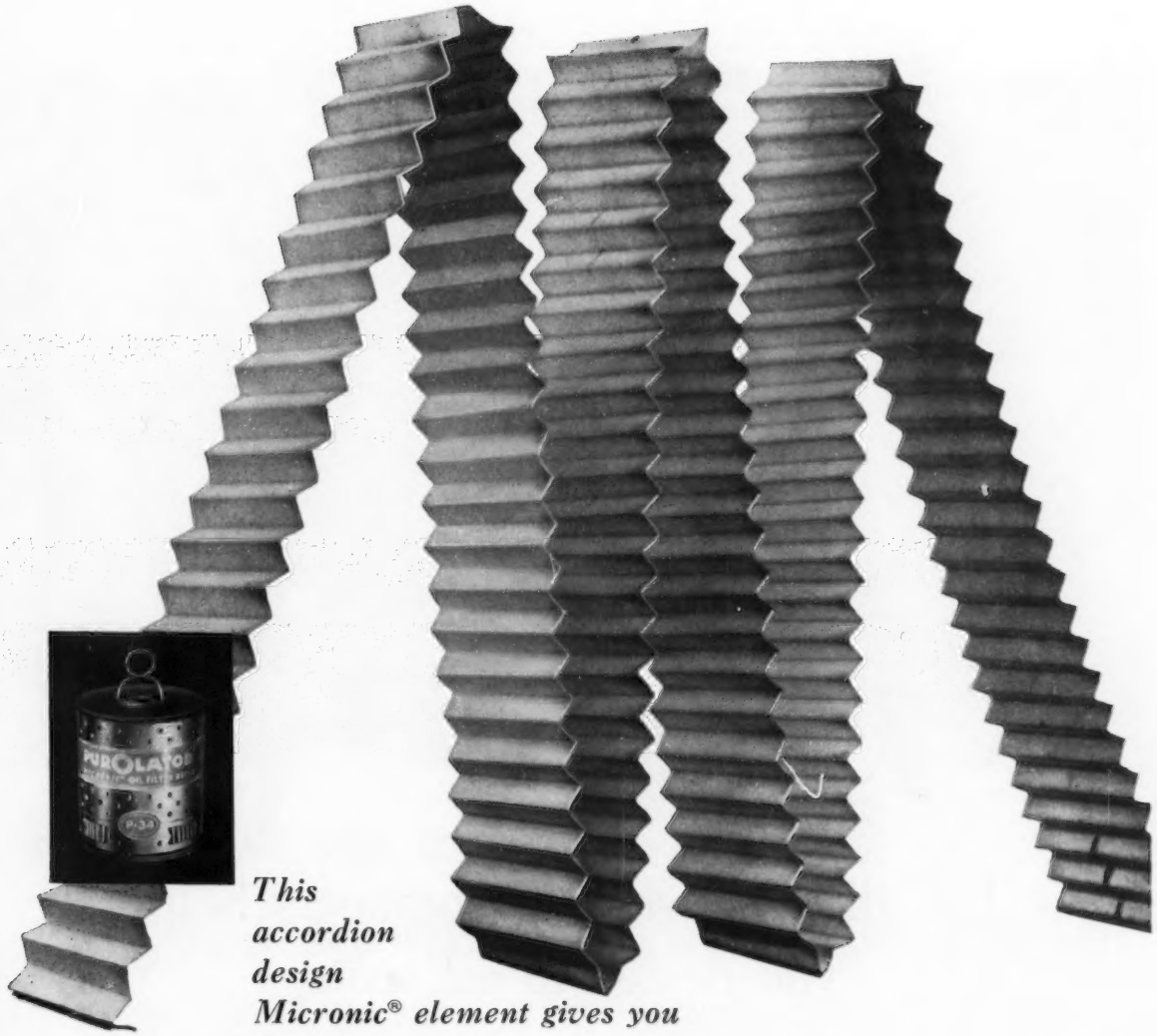
He obtained public patents for free use by the people on cotton drying processes, cotton cleaning devices, insect killing devices, etc.

A rather comical coincidence exists in connection with his work with dryers. His grandmother, uncle and brother had been given the middle name of "Dryer". Although he had not been so-named, he suggests that it might account for one of the reasons why he has been so interested in the subject of dryers.

In 1946 he was presented the Bronze Distinguished Service Medal by the University of Nebraska as an outstanding alumnus for his leadership in engineering achievement in the cotton industry. He received an Award Certificate from the Texas Cotton Ginners' Association, in 1949, for the professional engineering contributions made to the art of ginning, and in 1956 he received a certificate in recognition of the completion of thirty years of service in the U.S. Department of Agriculture.

Besides his contributions to agriculture, he has been active in the Masonic Lodge and other civic organizations. He is a 33 degree Honorary Mason in the Southern Jurisdiction of the Ancient and Accepted Scottish Rite, an honor which was accorded him in Mississippi in 1941. He has been a member of the Lodge Building Committee of the Grand Lodge of Mississippi since 1937.

His new address is 3202 Peck Ave., San Pedro, Calif.



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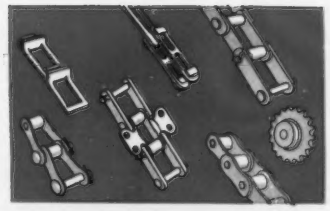
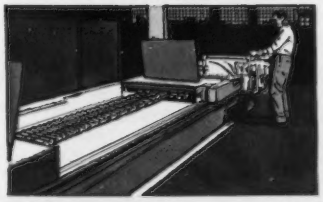


COMPLETE LINE of agricultural chains, sprocket wheels and attachments permits cost-saving specialization — offers right chain for all conveyor and drive needs.



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John Deere Grain Drills

...*"They're Tailored to Fit the Farm"*

From county to county—in fact, almost from farm to farm—planting methods vary greatly. The crop, the soil, the acreage, the available power—all are factors that influence the farmer in choosing the equipment to handle his planting jobs. To meet these many and varied demands, John Deere not only manufactures grain drills in all practical types and sizes, but makes each individual drill readily adaptable to the exact requirements of the individual owner. That's why farmers the world around look to the John Deere line and find there the drill that gives them the kind of planting job they seek.

Of course, in spite of the obvious differences in drills, there are some qualities demanded of every good drill and which all John Deere Drills have in common. Foremost among them are planting accuracy, convenient adjustments, and long life. These are the weighty values that seem inevitably to tip the scale of farmer opinion in the favor of John Deere Grain Drills.

John Deere Fertilizer-Grain Drills, Plain Grain Drills, Press Grain Drills, Lister and Mulch-Hoe Grain Drills, and Plow-Press Grain Drills are all leaders in their respective areas of use.

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"Wherever Crops Grow, There's a Growing Demand for John Deere Farm Equipment"

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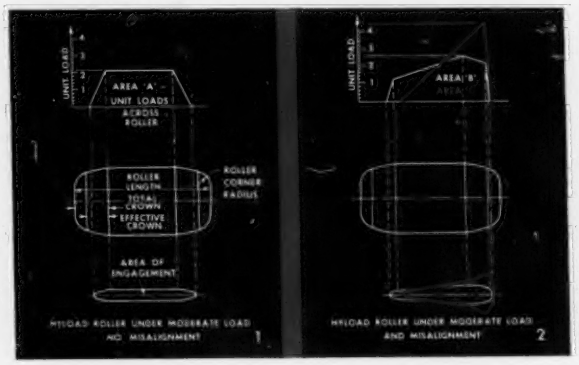
ONE OF A SERIES . . .

What makes Hyatts run smoother and longer?

PROPER LOAD DISTRIBUTION ON ROLLERS

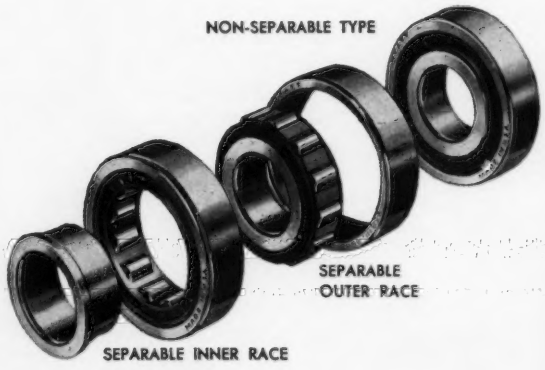
In any roller bearing, the design and quality of the rollers themselves vitally affect the performance of the entire bearing. The distribution of the load, both within the roller's area of contact and across the roller, must be expertly engineered. End-loading and conditions of misalignment can seriously reduce the life of a roller bearing. How HYATT minimizes these effects is detailed at the right.

You will find full selection and application data in HYATT Catalog 150, or call your nearest HYATT Sales Engineer. Hyatt Bearings Division, General Motors Corporation, Harrison, N.J., Pittsburgh, Detroit, Chicago and Oakland, Cal.



ROLLER CROWNING MINIMIZES EFFECTS OF BEARING MISALIGNMENT

The unit load on any roller is distributed axially in a uniform manner except at the ends where crowning has been provided. Figure 1 shows how the unit load drops off to zero at the ends of the area of contact. The summation of unit loads represented by area "A" is the total roller load. This same load under conditions of misalignment (Figure 2) must result in an area "B" equal to area "A"; but the maximum unit load is considerably greater and the misaligned bearing will therefore have a shorter life. However, if the same total load is applied to an uncrowned roller in a misaligned bearing, as shown in red, a much higher unit load (area "C") results, which would still further reduce the life of the bearing. This demonstrates graphically why HYATT Hy-Load Series Bearings with roller crowning will run smoother and longer under conditions of misalignment.



GM GENERAL MOTORS

HYATT HY-ROLL BEARINGS FOR MODERN INDUSTRY

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Report to Readers . . .

MORE MILLIONS FOR ENGINEERING RESEARCH SETS NEW PACE IN FARM EQUIPMENT INDUSTRY

Largest unit in the industry (Harvester), as its president, Peter V. Moulder, announced to an ASAE meeting audience recently, is establishing a farm equipment engineering and research center with a laboratory to cost in excess of $5 million to house a 1,000-man team of scientists, engineers, and farming specialists to spearhead the company's program of bringing out better and ever better farm equipment. Other companies in the industry are also moving in the same direction. . . . Evidence such as this presages an even faster pace in the development of new and improved implements and machines in the years immediately ahead than has been true even of the recent past. . . . This promising trend is of special significance to that growing list of companies that supply many of the essential components used in modern farm machines and on whom the industry is so largely dependent in producing products of top quality and performance.

"NEEDED: A SUBSTITUTE FOR A TEAM OF MULES"

Under this title, elsewhere in this issue, G. B. Gunlogson presents an interesting case for the "small" farmer as an important segment in our American free-enterprise system — and for more two-mule-power equipment to raise the level of his operating efficiency. . . . Mr. Gunlogson concludes with this statement: "Various recent developments of methods and materials, including air-cooled engines, V-belt drives, etc., may suggest some new approaches to the type of engineering we have in mind. Indeed it presents a new challenge for the farm machinery industry." . . . The small farmer is as essential to a well-rounded agriculture as is the small businessman to the general economy. Agricultural engineers and farm equipment manufacturers can well afford to devote more attention to his requirements, if for no other reason than that they represent a large potential market.

LOOK FOR MORE ATTENTION TO LAND SMOOTHING

The practice of land smoothing, or leveling, for removing "potholes," improving drainage, and reducing damage from erosion, has still not caught the popular fancy to any extent among agricultural engineers, but it has intriguing possibilities. It is noted that it is being studied by one state agricultural experiment station, and there are doubtless others. . . . This development is a "natural" for agricultural-engineering attention. Also, some of the equipment companies are going full speed ahead to develop its market possibilities for their products.

LIQUID FEEDS ENTER FARMING PICTURE

First it was liquid fertilizers to come into the limelight; now it's liquid feeds. "Successful Farming" for January had a story on it, and comments Engineering Editor DeForest: "It may greatly influence livestock feeding, because (1) many ingredients that cannot be manufactured, stored or transported in dry form can be fed in liquid carrier, (2) cost of manufacturing and storing liquid feeds is less, (3) they are easily handled, especially by automatic means, and (4) damage from rodents and insects is practically eliminated." . . . All this means new challenges for engineers and manufacturers to provide the engineering and equipment necessary for putting the idea to work.

EXPANSION OF FARM STORAGE FACILITIES ENCOURAGED

It will be welcome news to manufacturers of storage structures and structural materials that the USDA is encouraging farmers to expand farm-storage facilities. It is pointed out that, under present price-support programs, farmers may find it economically advantageous to add to or improve farm storages, especially since they can obtain low interest rates on building loans up to 80 percent of the cost of a new structure. . . . It is also recommended by the USDA that, in planning additional storage, careful consideration be given to dual-purpose buildings to provide greater flexibility in adapting them to farm needs. . . . This will stimulate the demand for more information and counsel from agricultural engineers in both industry and public agencies to assist farmers with their storage problems.

NEW AND EASY WAY TO ADJUST FARM MACHINERY

What may develop into a whole new concept in farm machinery adjustment is being presented by L. W. HURLBUT, University of Nebraska agricultural engineer, in a series of articles in "Successful Farming", beginning with the February issue. The first article shows how alignment of key parts to a horizontal surface, and then alignment of secondary parts will put the machine in adjustment — the way the engineer designed it. . . . This work may help to nudge manufacturers into giving more attention to improving operator manuals.

FENCE POSTS: CHEAPER TO "DRIVE" THEM OR "SET" THEM?

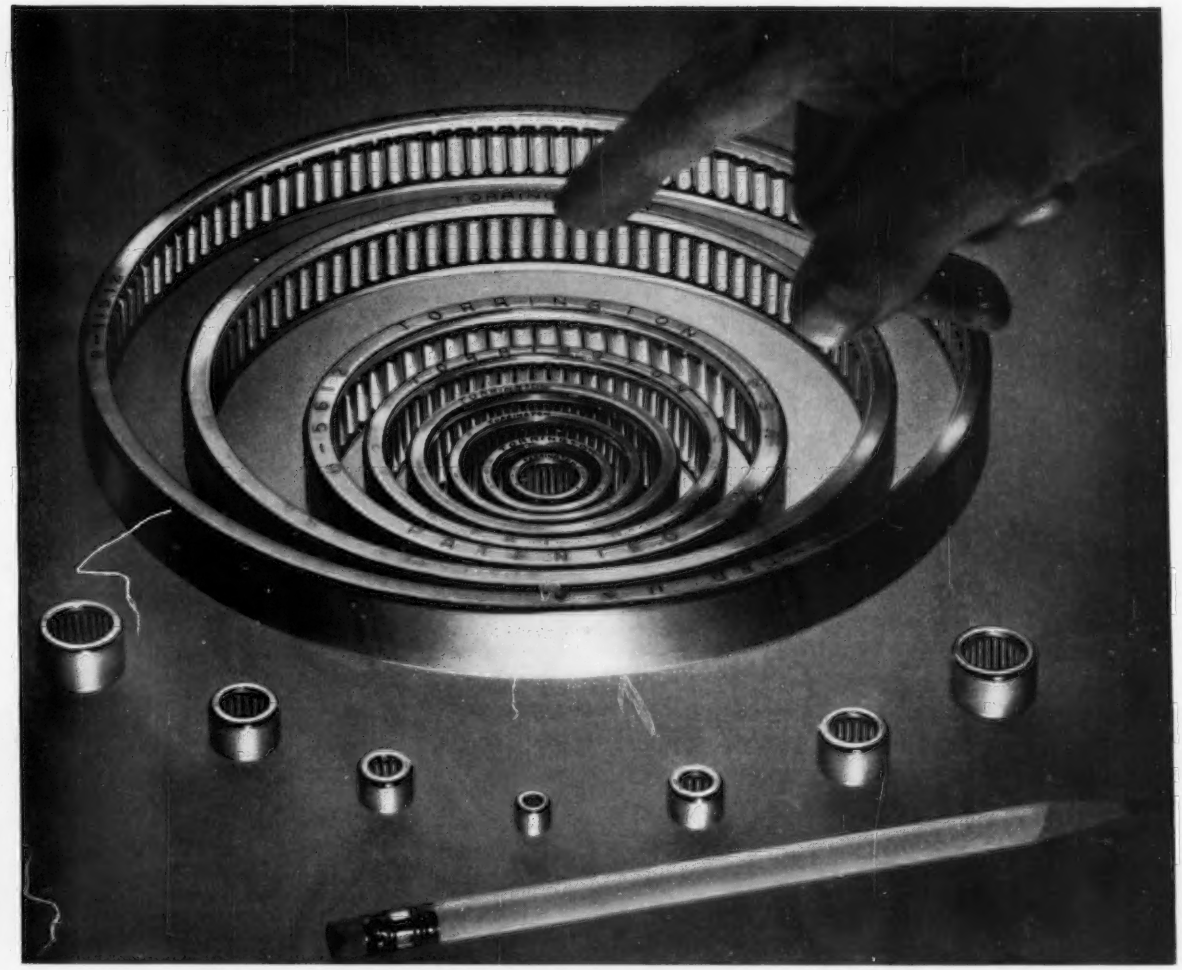
One state agricultural experiment station (North Dakota) is making a comparative cost study of two methods of erecting fence posts, in which power driving of posts will be compared with setting them by the power-auger-and-hand-tamping method. . . . Of course, an unlimited variety of ground conditions go along with the job of erecting fence posts. The prevailing condition in each case, however, will largely determine what method is cheaper — and what equipment is best suited for the work. One thing is certain: whatever equipment is used, the farmer will want it powered by an internal-combustion engine or an electric motor. . . . This small sector of farm mechanization should prove an attractive market for a rather limited number of small manufacturers.

HOW ENGINEERS HELP BOOST FARM MACHINERY SALES

One top farm-equipment-industry official indirectly credited industry engineers when he predicted a substantial increase in farm machinery sales this coming season. He stated that new and improved products to be introduced this year were designed to effect more labor saving, more economy and more profit for farmers because of the greater efficiency and capacity of this equipment to do the job for which it is intended. . . . For some time the heat has been on industry engineering departments to help stem the tide of slumping farm equipment sales, by developing improvements and new equipment to continue the job of making that "good farmer better." These engineers do indeed hold the master key to producing what farmers need and will buy — and they have been using it to unlock the door to improved sales.

"THAT HE MAY RUN THAT READETH IT"

Our "Report to Readers" aims to pinpoint things believed to be of current and more than passing interest. Suggestions of ideas and information to feature are always welcome. They must be kept short and to the point, however, to catch the eye of readers on the run, as most readers are these days in trying to keep pace with the reams and reams of the printed word daily crossing their desks.



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See our New Needle Bearing Catalog in the 1956 Sweet's Product Design File —or write direct for a catalog.

TORRINGTON NEEDLE BEARINGS
Give you these benefits

- low coefficient of starting and running friction
- full complement of rollers
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- low unit cost
- long service life
- compactness and light weight
- runs directly on hardened shafts
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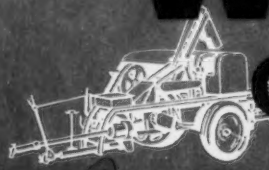
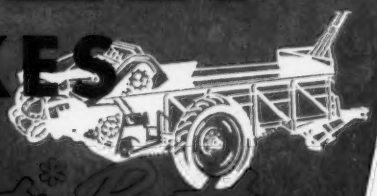
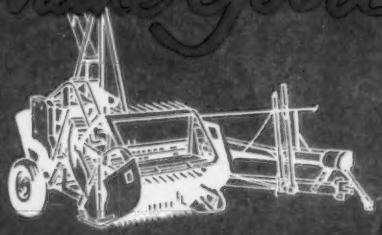
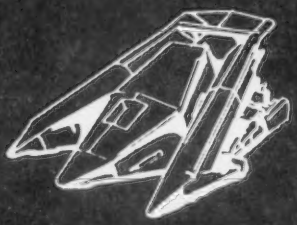
GEAR BOXES





Make Good Products Better





***FIELD CUTTERS, COMBINES, HAY BALERS, FORAGE HARVESTERS, CORN PICKERS**

Many a farm implement is no better than its gear box. That's why more and more leading manufacturers of rotary cutters, hay balers, combines, forage harvesters and other tools are standardizing on WARNER Gear boxes.

Every Warner Gear box is designed and engineered to transmit power efficiently and dependably, to withstand heavy shock loads. Built rugged, too—with automotive type gearing . . . carburized and hardened gears . . . anti-friction bearings throughout, individually selected for load . . . integrally forged gear and shaft . . . malleable iron housings when necessary.

What's more, Warner mass production techniques and facilities mean lower costs. So if you have a gear box problem, send it to Warner. No obligation, of course.

WARNER

AUTOMOTIVE PARTS DIVISION

ENGINEERING B-W PRODUCTION

Borg-Warner Corporation
Auburn • Indiana

Products of Experience

Now! Two big ways 1957 IH Tractors put power to better use!

NEW "TC"
TRACTION-CONTROL FAST-HITCH

PLUS TA
TORQUE AMPLIFIER

. . . gives you PULL-POWER second to none!

Say goodbye to frequent shallow-ups and shiftdowns! Here's your *double-barreled* answer to tough spots—new Fast-Hitch with Traction-Control, plus Torque Amplifier! See how this great combination of "grip and go" gives new McCormick® Farmall® 350, 450, and International® 350 Utility tractors pull-power out of all proportion to rated horsepower.

IH Traction-Control Fast-Hitch gives you continuous traction that *grows with the load!* This keeps you plowing full depth when others can't.

To give your IH tractor its second wind, just pull the Torque Amplifier lever. Instantly, without shifting, TA increases drawbar pull up to 45% to keep you plowing non-stop! This surging power-punch teamed with ground-gripping traction makes you master of the toughest plowing on your farm!

Call your IH dealer . . . he'll gladly demonstrate. Feel the "grip and go" of traction that grows with the load and the power-punch of TA. Try the new 4-plow Farmall 450 . . . 3-plow Farmall 350, or International 350 Utility.

NEW PILOT GUIDE
At a glance . . . Pilot Guide tells plowing depth and whether you have the right amount of weight transfer to match soil condition. Try "look-ahead" farming!

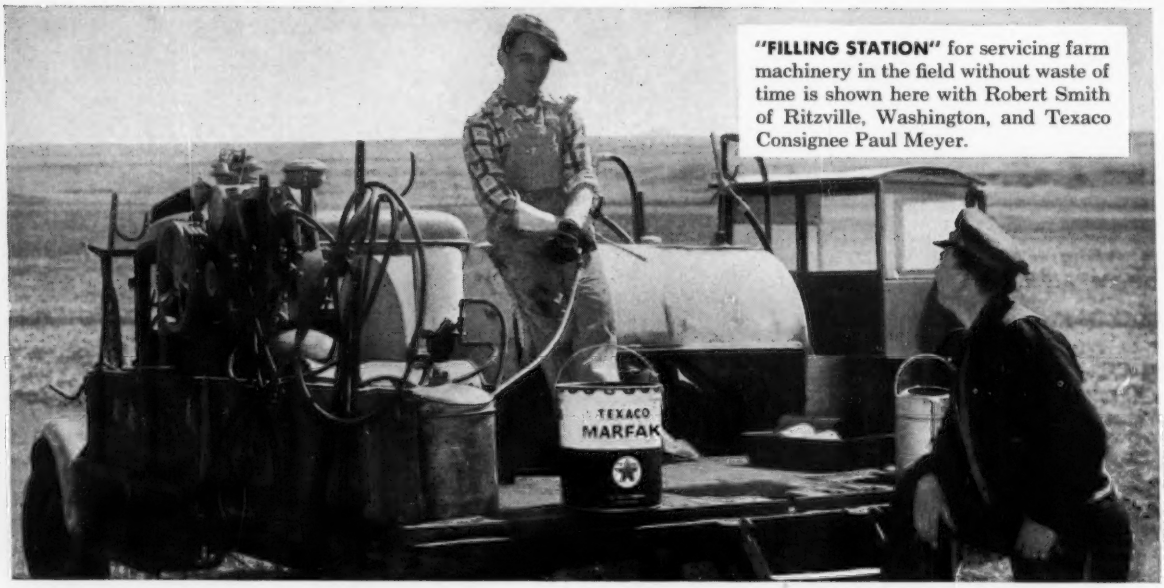
Outplow them all with the "grip and go" of this new Farmall 450—pulling a new McCormick 4-furrow Fast-Hitch plow with individual spring trip beams.

See your INTERNATIONAL HARVESTER Dealer

International Harvester products pay for themselves in use—McCormick Farm Equipment, Farmall and International Tractors . . . Motor Trucks . . . Construction Equipment—General Office, Chicago 1, Illinois

For more facts circle No. 67 on reply card

Service Station on Wheels *saves time and money*



"FILLING STATION" for servicing farm machinery in the field without waste of time is shown here with Robert Smith of Ritzville, Washington, and Texaco Consignee Paul Meyer.

ROBERT and VERNON SMITH operate a 1280-acre wheat farm. They developed this "service station on wheels" for fast fueling and lubrication of machinery during field work. It carries two 150-gallon tanks, one for Fire Chief gasoline and the other for Diesel Chief fuel. Most important, it has an air compressor for lubrication, complete with long hose and fittings. These brothers know the value of constant lubrication – their machines are greased regularly with MARFAK.

In addition to having a plentiful supply of MARFAK on the field truck, their farm headquarters shop has for eight years been fully stocked with other Texaco products.

Progressive farmers like these, *everywhere*, have found that *it pays to farm with Texaco products.*

FRISKY "HAY BURNER" held by B. V. Montgomery of near Eaton, Ohio, is admired by Texaco Consignee H. J. Miller (second from right), who provides Mr. Montgomery with Fire Chief gasoline and always *dependable, on-time* farm service for other Texaco products.

IN TOWN OR ON THE HIGHWAY—wherever you drive—in all 48 states – you'll find Texaco Dealers *serve you best.* High octane Sky Chief gasoline, super-charged with Petrox, to assure maximum power and cut engine wear... famous Fire Chief gasoline at the *regular* price, both 100 per cent *Climate-Controlled.* Also Advanced Custom-Made Havoline Motor Oil and Marfak lubricant.

ADVANCED CUSTOM-MADE HAVOLINE MOTOR OIL wearproofs truck, tractor and car engines – gives added power, longer engine life, greater gasoline mileage. No other oil can match it, *regardless of price.* J. T. Pitts, San Benito, Texas, gets Havoline and other Texaco products from Texaco Consignee A. L. Dodson.

ON FARM AND HIGHWAY IT PAYS TO USE

TEXACO

PRODUCTS

DIVISION OFFICES: Atlanta, Ga.; Boston 16, Mass.; Buffalo 9, N. Y.; Butte, Mont.; Chicago 4, Ill.; Dallas 2, Tex.; Denver 3, Colo.; Houston 2, Tex.; Indianapolis 1, Ind.; Los Angeles 15, Calif.; Minneapolis 3, Minn.; New Orleans 16, La.; New York 17, N. Y.; Norfolk 2, Va.; Seattle 1, Wash.

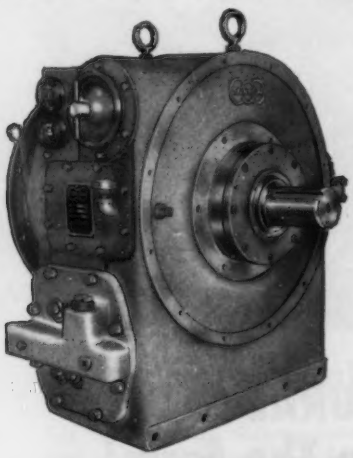
Texaco Products are also distributed in Canada, Latin America, and Africa.

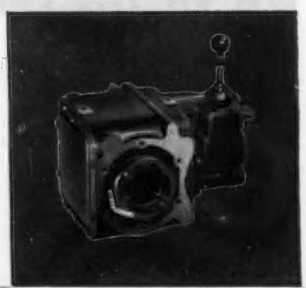
TUNE IN . . . Metropolitan Opera radio broadcasts every Saturday afternoon. See newspaper for time and station.

THE TEXAS COMPANY

How to Make Sure of Superior Performance

CLARK-TORCON CONVERTER UNIT





Who can build the best machine!—that is the modern spirit of American Industry. And the intensity of that competition is a major reason why leading manufacturers are using Clark engineering cooperation in designing new equipment—highway and off-highway, automotive, industrial, and construction.

For *Clark knows the transmission of horsepower:* has specialized in that basic field for more than 50 years; knows what can be counted upon to work—and what will not . . . The drive-units pictured here were designed to *make sure* of superior performance. They are hard-working, rugged, dependable proofs that it's good business to do business with Clark Equipment.

Send for attractive pocket-size booklet "Products of Clark".

CLARK EQUIPMENT COMPANY
JACKSON, MICHIGAN
Other Plants:
Buchanan, Battle Creek, Benton Harbor, Michigan

CLARK® EQUIPMENT

For more facts circle No. 69 on reply card

MANHATTAN AGRICULTURAL BELTS
Keep Power at Work on The Farm!

Manhattan Agricultural Belts keep their tension and flexibility in all kinds of weather to assure positive power delivery and long service life where it counts the most—in the field!

For day-in, day-out dependability on the job, Manhattan Agricultural Belts have earned the confidence of leading farm equipment manufacturers. Manhattan belt engineers draw on more than 60 years of rubber research, development and production experience to work with the manufacturer in designing trouble-free transmission drives . . . for all types of belted power applications.

R/M engineers are ready to help you solve *your* belt problems with dependable Manhattan Agricultural V-Belts, Condor Whipcord Endless Belts and new, patented R/M Poly-V® Drives. Let R/M show you how you can meet the most rigid specifications for present and new drive designs . . . add "More Use per Dollar" to every unit of belt driven equipment you manufacture.

Poly-V is a registered Raybestos-Manhattan trademark.

RM703

BELTS • HOSE • ROLL COVERING • TANK LININGS • INDUSTRIAL RUBBER SPECIALTIES

MANHATTAN RUBBER DIVISION—PASSAIC, NEW JERSEY

RAYBESTOS-MANHATTAN, INC.

Other R/M products: Abrasive and Diamond Wheels • Brake Blocks and Linings • Clutch Facings • Asbestos Textiles • Mechanical Packings • Engineered Plastics • Sintered Metal Products • Industrial Adhesives • Laundry Pads and Covers • Bowling Balls

Farm implement dealers cooperated with the Watonwan County, Minn., Safety Council, to stress the dangers of unguarded power take-off shafts in this county fair exhibit. "Empty chairs" mean "empty tractor seats" too!

Photo courtesy of
Watonwan County Safety Council

BLOOD BROTHERS *Integral*

Safety-Shielded Drive Lines help farm implement dealers keep their customers safe!

For humanitarian reasons—and wise business practice as well—it pays to increase the customer's safety in every possible way. As proof of great progress in the farm implement field, Blood Brothers reports an increase of over 300% in the demand for Integral Safety-Shielded Drive Lines during the past year alone!

Some manufacturers are supplying Integral-Shielded Drives exclusively on *all* power take-off implements they build. This trend to greater safety helps implement builders—dealers—users—everyone!

Saleswise, Blood Brothers Integral-Shielded Drive Lines are helpful too. They offer a strong "plus" selling feature that *proves* you place the farmer's best interests *foremost.* Designed to avoid careless or absent-minded removal, they'll be *in place* to protect implement operators at all times.

If you *build* implements, write for information on the sizes you need.

FOR FARM IMPLEMENTS, MORE BLOOD BROTHERS UNIVERSAL JOINTS ARE USED THAN ALL OTHER MAKES COMBINED

TAKES POWER AROUND CORNERS

BLOOD BROTHERS MACHINE DIVISION
ROCKWELL SPRING AND AXLE COMPANY
ALLEGAN, MICHIGAN

UNIVERSAL JOINTS AND DRIVE LINE ASSEMBLIES

FOR BETTER FARM BUILDING

Recommend Kaiser Aluminum Roofing

Kaiser Aluminum Roofing gives farmers all of the benefits of aluminum, plus an unrivaled record of freedom from wind damage and nail pull-through.

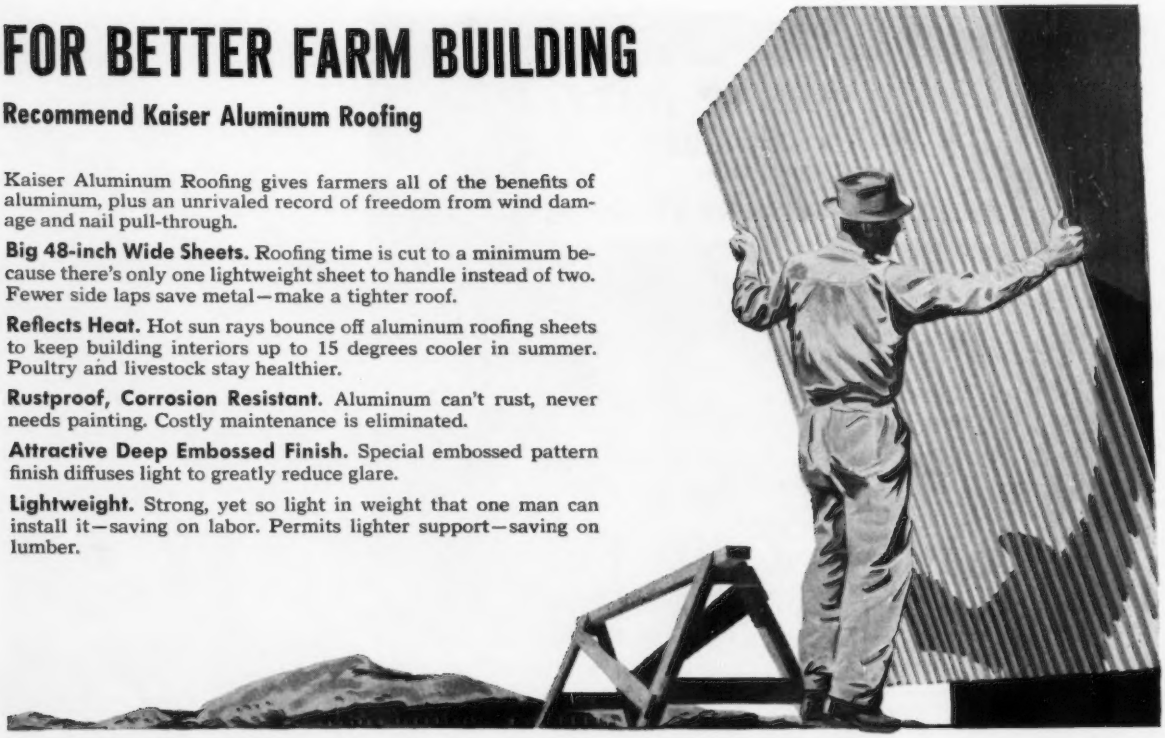
Big 48-inch Wide Sheets. Roofing time is cut to a minimum because there's only one lightweight sheet to handle instead of two. Fewer side laps save metal—make a tighter roof.

Reflects Heat. Hot sun rays bounce off aluminum roofing sheets to keep building interiors up to 15 degrees cooler in summer. Poultry and livestock stay healthier.

Rustproof, Corrosion Resistant. Aluminum can't rust, never needs painting. Costly maintenance is eliminated.

Attractive Deep Embossed Finish. Special embossed pattern finish diffuses light to greatly reduce glare.

Lightweight. Strong, yet so light in weight that one man can install it—saving on labor. Permits lighter support—saving on lumber.



FOR BETTER FARM IRRIGATION

Recommend Kaiser Aluminum Irrigation Tubing—it's *Kladlined**

Kaiser Aluminum Kladlined Irrigation Tubing gives farmers the greatest advantages of any irrigation pipe for sprinkler and gated systems . . . at no extra cost.

Greatest Weight Advantage. Weighs less than 22 pounds†. ⅓ the weight of galvanized.

Greatest Bursting Strength. Hydrostatically tested with pressures of 450 p.s.i. Insures resistance to surge pressures.

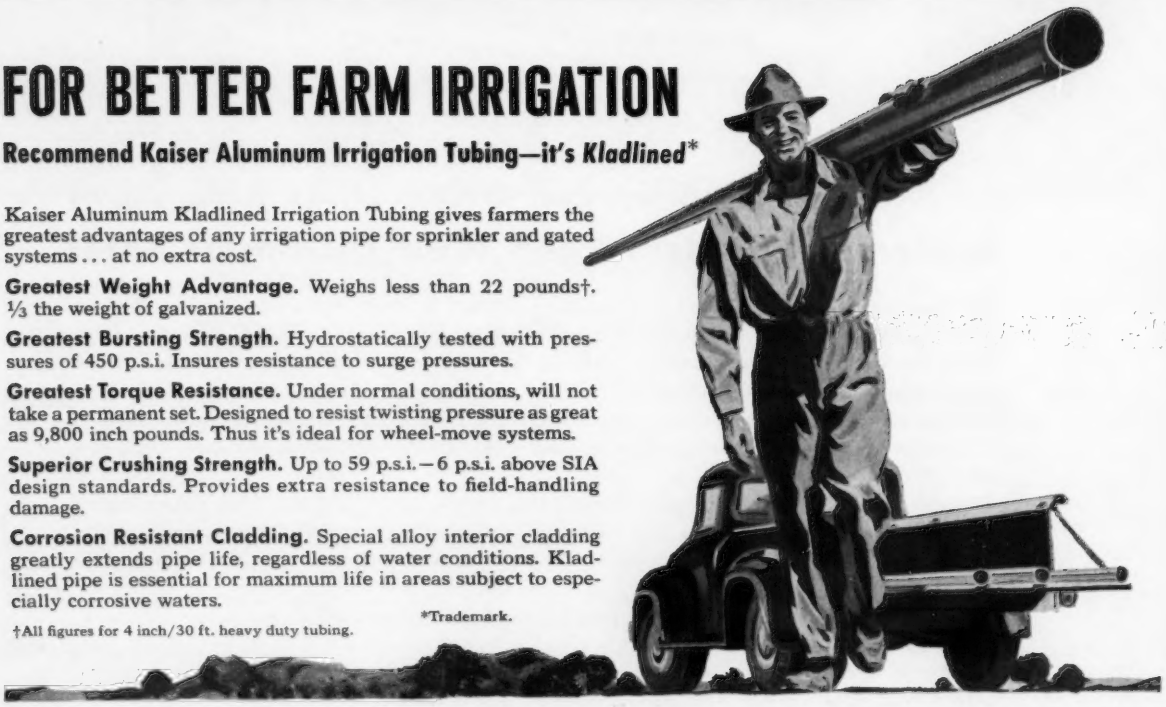
Greatest Torque Resistance. Under normal conditions, will not take a permanent set. Designed to resist twisting pressure as great as 9,800 inch pounds. Thus it's ideal for wheel-move systems.

Superior Crushing Strength. Up to 59 p.s.i.—6 p.s.i. above SIA design standards. Provides extra resistance to field-handling damage.

Corrosion Resistant Cladding. Special alloy interior cladding greatly extends pipe life, regardless of water conditions. Kladlined pipe is essential for maximum life in areas subject to especially corrosive waters.

*Trademark.

†All figures for 4 inch/30 ft. heavy duty tubing.



Kaiser Aluminum Roofing and Kaiser Aluminum Kladlined Irrigation Tubing increase farm efficiency, at low cost, from the ground up. For further information concerning either of these quality Kaiser Aluminum products please contact Kaiser Aluminum Agricultural Research Service, Merchant Products Dept. AE, 919 N. Michigan Ave., Chicago 11, Illinois.

Kaiser Aluminum

A Quality Line for Better Farm Building

See "THE KAISER ALUMINUM HOUR." Alternate Tuesdays, NBC Network. Consult your local TV listing.

BCA

Standard . . . or custom-made

BCA BALL BEARING PACKAGE UNITS

improve implement performance . . . reduce manufacturing costs

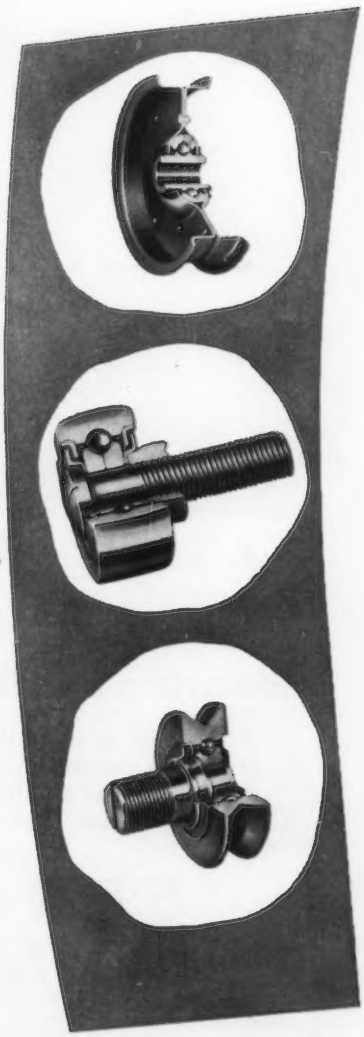
There are two ways in which you can benefit from BCA's long experience in the design and production of pre-lubricated ball bearing package units for farm implement applications.

- Use standard BCA package units on your assembly line.
- Count on BCA for skilled assistance in designing custom-made package units for special applications . . . or for use in new implements you plan to manufacture.

Choose one or the other . . . or both. You will find that you can reduce assembly time and costs . . . improve product performance, too.

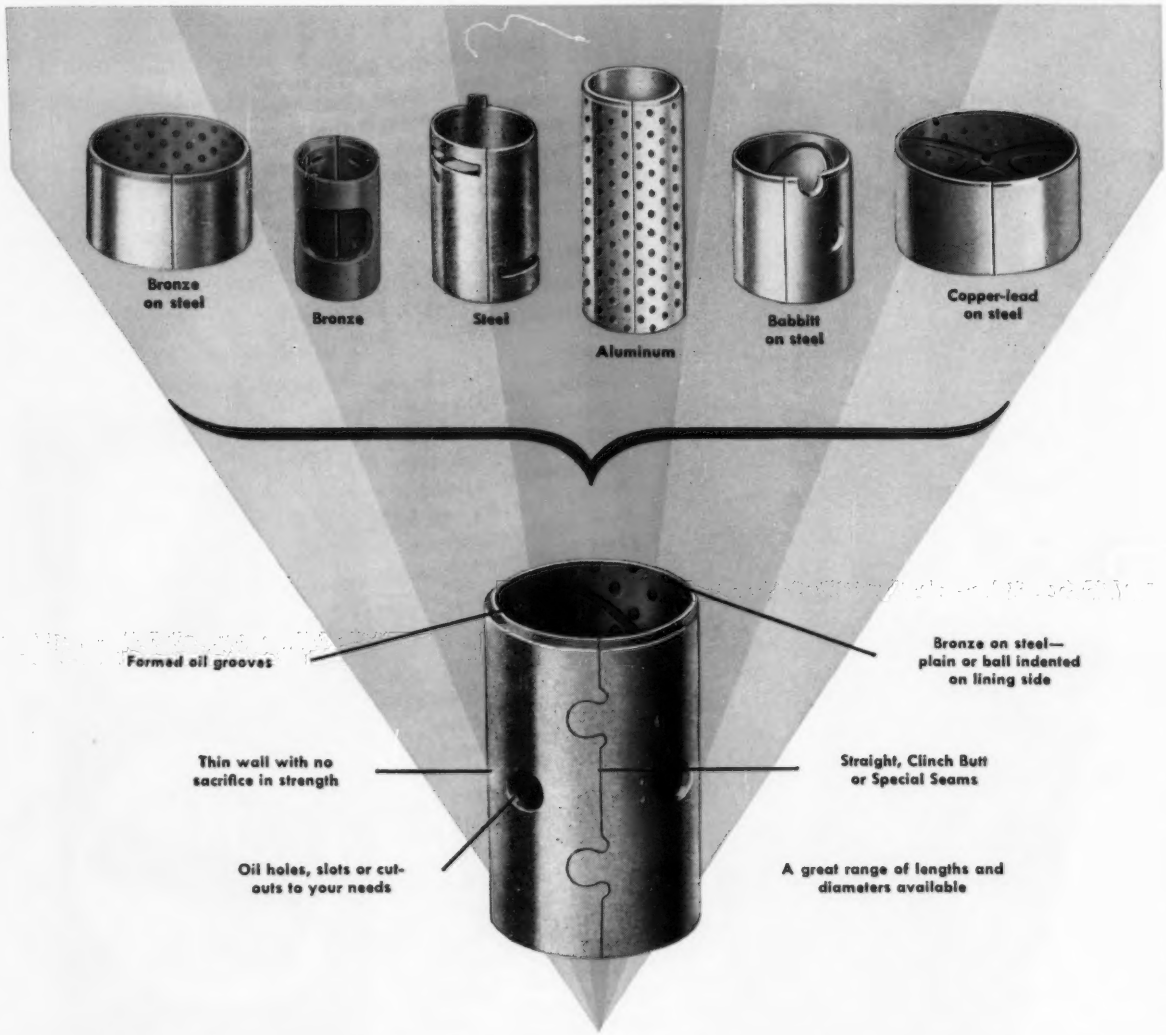
BCA packaged units combine the bearing, its housing, and an effective seal in a single rugged unit capable of handling the loads, speeds and operating conditions encountered in farm work. Lubricated for life, standard packaged units are available for many applications including idler pulley assemblies . . . cam followers . . . plunger rollers . . . hay rake bearings . . . grains drills . . . others.

BCA pioneered the development of pre-lubricated package units for agricultural use . . . can help you find the right answers to any ball bearings problem you may have.



BCA
Bearings Company of America Division

Federal-Mogul-Bower Bearings, Inc.


Bronze on steel
Bronze
Steel
Aluminum
Babbitt on steel
Copper-lead on steel
Formed oil grooves
Bronze on steel—plain or ball indented on lining side
Thin wall with no sacrifice in strength
Straight, Clinch Butt or Special Seams
Oil holes, slots or cut-outs to your needs
A great range of lengths and diameters available

Bearing Performance with Bushing Economy

Any of these design features can be incorporated in our plain or bi-metal bushings. For many applications lower cost bushings provide the needed bearing characteristics at a distinct price advantage. We provide a complete engineering service. Address:

FEDERAL-MOGUL

DIVISION, Federal-Mogul-Bower Bearings, Inc.
11081 Shoemaker, Detroit 13, Michigan

BABBITT-LINED BEARINGS

BEARING-SURFACED THRUST WASHERS

SPACER TUBES

COPPER-LEAD BEARINGS

FEDERAL Mogul

SINCE 1899

RESEARCH • DESIGN • METALLURGY • PRECISION MANUFACTURING

Alcoa can help you help farmers

Alcoa® researches farm applications of aluminum continuously. Take buildings . . .

In cooperation with leading agricultural colleges throughout the country, Alcoa has developed nine plans for practical pole-type buildings that can be built at savings up to 75%. More important than first cost are the long-range savings on upkeep and the increased livestock production that result from the animal comfort which aluminum brings.

You can have one complete set of these building plans free by writing for it. In addition, there's a big catalog describing these plans and giving a run-down on the savings and other advantages of building with aluminum.

If you have questions about aluminum on the farm, why not give Alcoa a chance to help you answer them? We'd like to hear from you. Meanwhile, here are some materials you'll be glad to have in your files. Write for them.

THE ALCOA HOUR
TELEVISION'S FINEST LIVE DRAMA
ALTERNATE SUNDAY EVENINGS

ALCOA SALUTES

Your Guide to the Best in Aluminum Value

ALCOA ALUMINUM
FARM PRODUCTS
ALUMINUM COMPANY OF AMERICA
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Agricultural Division
Aluminum Company of America
2089-C Alcoa Building, Pittsburgh 19, Pa.

(Please send items checked)

- ☐ One complete set of nine pole-building StePlans.*
- ☐ *Pole Barn Plans Catalog.* Lists Alcoa plans available to farmers.
- ☐ *Pipelines to Profit.* Booklet on portable irrigation.
- ☐ "Right as Rain" 28-minute sound-color film on portable irrigation.†
- ☐ "Barn Raising, U.S.A." 18-minute sound-color film on pole barn construction using aluminum roofing and siding.†
- ☐ Alcoa Farm Gate literature. Facts about aluminum gates.

*Trademark of Aluminum Company of America
†Films may be borrowed for public showing. Specify dates wanted

Name_____

Address_____

Post Office and State_____

For more facts circle No. 73 on reply card

Massey-Harris Goble No. 27 Flexible Disc Harrow equipped with Ingersoll Discs, pulled by Massey-Harris 555 Tractor

"SHRINKING" Big Acreage with Ingersoll Discs

Here's a big-acreage team that works the soil uniformly to make a fine seed bed in the shortest possible time. It's the Massey-Harris Goble 27 Flexible Disc Harrow equipped with big, sharp Ingersoll discs.

Like all leading implement makers, Massey-Harris uses Ingersoll discs as original equipment. They've found that Ingersoll discs are tough and springy to take heavy impact, hold a knife-edge longer and resist splitting, curling, warping and abrasion.

The secret is in the steel . . . TEM-CROSS® steel, produced only by Ingersoll. It's the finest tillage steel in the world . . . cross-rolled to develop a super-tough grain structure that withstands tremendous stresses . . . heat-treated by an exclusive Ingersoll process for proper hardness with uniform tempering.

Give your customers the best by ordering Ingersoll discs whenever replacements are needed. You get them direct from your implement manufacturer.

Ingersoll *Heat Treated* **Discs**

ENGINEERING B-W PRODUCTION T.M.

Ingersoll

PRODUCTS DIVISION

BORG-WARNER CORPORATION, CHICAGO 43, ILL.

EXPORT SALES: *Borg-Warner International, 36 S. Wabash Ave., Chicago 3, Ill.*

SPECIALISTS IN TILLAGE STEELS • WORLD'S LARGEST MANUFACTURER OF DISCS

Agricultural Engineering

March, 1957
Volume 38
Number 3

James Basselman, *Editor*

Testimony . . .

BEFORE publication of the January issue of AGRICULTURAL ENGINEERING, in which the "new look" was introduced, it was decided that representative letters from readers commenting on the change would be printed. The "likes" and "dislikes" would be carried in proportion to the response. To our happy surprise all who bothered to write had nice things to say. This, of course, was most encouraging.

In order that others may know what some have said and how they feel about the "new look," the following excerpts have been selected as representative samples:

"Congratulations on the new design of the AGRICULTURAL ENGINEERING Journal. It is very attractive and makes the Journal even more useful.

"The report to readers page is very interesting, and I think a help to us who have difficulty finding time to keep up with all the new happenings in our field.

"Mr. Dreyfuss has provided an interesting new cover which adds to the attractiveness of the Journal."

David H. Huntington
Assistant Professor, Agr. Eng.
University of Maine

"The new format is attractive and a big improvement, adding dignity to the entire organization. It's everything that advance reports promised. The front cover is a credit to any publication."

W. Everett Eakin
Farm Promotion Manager
Libbey-Owens-Ford Glass Co.
Toledo, Ohio

"Our staff members were very much interested to see the January issue of AGRICULTURAL ENGINEERING in which you employed your new format. Our folks are very enthusiastic about the new look. Congratulations."

Arthur W. Farrall, Head
Agricultural Engineering Dept.
Michigan State University

"Congratulations on the makeup of the Journal. A farmer out in the state who takes the Journal said last week that he got a lot of good information from it and felt that the information printed was way ahead of most other farm magazines. Keep up the good work."

A. J. Lambert, Secretary
Virginia Section ASAE

"...I am confident that the changes will reflect credit to our Society. I know nothing about the publishing business, but it seems to me that this new magazine would certainly have more appeal to all of our members. The articles on self-feeding silo, fluted nails, new hitch design, bulk milk cooling, and recharging ground water are of vital interest to all of us in the agricultural engineering profession."

J. W. Martin, Head
Agricultural Engineering Dept.
University of Idaho

"Congratulations on AGRICULTURAL ENGINEERING'S new look! . . . I think this innovation will meet with enthusiastic approval."

George B. Nutt, Director
Extension Service
Clemson Agricultural College

"For whatever it is worth to you, you have my big bouquet for the improvement in the Journal."

H. N. Stapleton
Shelburne Farms
Shelburne, Vt.

"Many congratulations on the splendid change in our Journal. The benefits to readers are infinite."

Rex T. Lyle
Wheat Farmer
Cunningham, Wash.

"On behalf of the Alabama Student Branch of ASAE I would like to express our views on the new format of AGRICULTURAL ENGINEERING. We think it is a 100 percent improvement and that the editor and all those connected with the Journal should be commended for the good work they are doing."

Coy W. Doty, Secretary
Alabama Student Branch ASAE
Alabama Polytechnic Institute

"I was shocked and a bit annoyed when I first saw the new format of AGRICULTURAL ENGINEERING. However, on careful examination I realized that it is a great improvement. I think that both readers and advertisers will be pleased."

R. P. Messenger
Former Vice-President
International Harvester Co.

"You have accomplished the end of dressing up the book and giving it a modern look without losing any of its professional appearance. Also like the idea of that insert and the idea of the 'Report to Readers'."

Ellis B. Hillgrove, Jr.
Advertising Manager,
New England Homestead

"...I cannot close without complimenting you on AGRICULTURAL ENGINEERING'S 'new look.' It's not only attractive, but thoroughly in keeping with the professional character of the magazine and the important service it renders to agriculture."

R. A. Crosby
Advertising Manager
Farm Equipment Division
Allis-Chalmers Manufacturing Co.

"I wish to congratulate you and the others responsible for the appearance of the Journal. I think it's one of the best improvements that I have ever seen and I'm sure it will be a 'shot in the arm' to our Society."

P. R. Bakes
Farm Sales Supervisor
The Washington Water Power Co.

Farmall Cub built by International Harvester Company

Needed:

G. B. Gunlogson
Member ASAE

FOR several years various economic factors have given emphasis to the growing disparity between the so-called "small" (or low-income) and "big" farms. The term "small" is somewhat ambiguous in defining size of farms. Actually a 40-acre truck farm may be a bigger and more profitable operation than a 400-acre grain farm. This disparity derives largely from the difference in productiveness of farm land. Some farms have high productive potentials. Others are unproductive. The good farm lends itself to efficient operation. It can be and usually is highly mechanized. The poor farm can't afford the modern machinery now available.

The cost of farm labor is about four times higher than it was 20 years ago and in many sections of the country it is both scarce and incompetent. Many small operators, especially in the Southeast, depended for a long time on horses or mules and simple types of implements. Now the horse has practically disappeared. In fact, it is hard to find a horse collar except in an antique shop.

It is difficult to carry on any farming operation without power and certain other equipment. At the same time, the cost of modern power machinery has advanced to a point where it is now largely beyond the economic reach of roughly 40 percent of all farms in the country.

This increased cost of modern farm machinery is accounted for not only by higher costs of labor, materials, taxes, etc., but also by the many refinements which have been built into modern machinery, such as high speeds, time and labor-saving features, more precision engineering, etc. This machinery has gone a long way in providing increased capacity and time and labor-saving efficiencies for farmers who have productive land and adequate capital.

Two years ago I talked with a number of farmers in the Red River Valley in North Dakota. On one farm visited, two brothers were farming five quarters of land and had nearly 600 acres in crop. They estimated that with the machinery they had they could do all the work on these 600 acres in just a little over 100 days and hire very little outside help. The gross returns that year from this land were close to $24,000, or about $12,000 per man, or $120 per work day.

Modern machinery has made similar accomplishments commonplace in many farming areas, but on a vast number of farms such operations are still impractical or impossible for one reason or another.

Following is the number of farms by income groups according to 1955 census:

Group A	$2,500 or more income	2,101,000
Group B	$1,200 to $2,499 income	763,000
Group C	$1,200 or less (including part-time, residential, etc.)	1,919,000
	Total number of farms	4,783,000

The census reports that only 2,525,206 of these farms have tractors. Since the total number of tractors reported is 4,185,205, it means, of course, that many farms have two or more tractors.

It is estimated that Group A farms have at least 80 percent of all tractors, Group B possibly 15 percent, and Group C less than 5 percent. It can be assumed, I think, that other machinery or mechanization follows in about the same proportion.

Some economists argue that "poor farms" should be abandoned and that the occupants should take jobs in industry. This, in my opinion, is not the answer at all. In fact, many of their families now have some off-farm income, and the farm is their way of life. Small farmers form an important segment in our free-enterprise system. In many areas they occupy a position of independence and free choice between industry and farming.

When it comes to farm sizes, the trend for many years has been upward, but one-third of all farms are still under 50 acres in size and another 800,000 are under 100 acres.

Herein lies the challenge and the opportunity. Can the farm-equipment industry offer a type of power equipment that will meet in a measure the work requirements and come within the income limitations of this large group of "small" farms? It would in effect provide a modern substitute for the mule (or horse), and it would usher in a new day for a large number of people living on farms. It would open up a substantial new market for the industry.

Paper prepared expressly for AGRICULTURAL ENGINEERING.

The author—G. B. GUNLOGSON—is a long-time student of agricultural trends and conditions, a successful farm owner and operator, and former president of the Western Advertising Agency.

A Substitute for a Team of Mules

The author makes an interesting and logical case for the so-called "small" farmer as an important segment in our free-enterprise system—and for "two-mule-power" equipment to raise the level of his operating efficiency and economy

There is not much experience to go on and there are few machines now in use that meet these requirements. However, there are certain developments and observations worthy of mention.

1 The garden tractor and the large assortment of tools and attachments that have been developed to go with it are of some interest here. This equipment sells at a low price and yet a great deal of service and dependability have been built into it. The trend in design has been an interesting development to watch, embracing versatility, handy change of attachments, and a wide assortment of tools—all serviceable but relatively cheap. Most of these tractors are equipped with 2 to 5-hp air-cooled engines. The price of this equipment is surprisingly low. The sales have grown from a few tractors twenty years ago to about 200,000 in recent years. Currently sales may be down and it is suspected that this may be due partly to the large number of power mowers being sold, many of which are supplying power for the same gadgets.

The primary market for this equipment has not been the farmer but rather the suburban dweller who has an acre or two to play with. The large number of small farms under discussion here needs something much beyond the "garden" variety in power and capacity, yet these farms are not sufficiently large or productive to afford the conventional type of modern farm equipment now available.

2 There are two or three makes of tractors now on the market which come close to the requirements neded, but they are too costly. This modern "steel mule" under discussion would probably have a 9 to 12-hp engine, and simplicity, accessibility and low price are prime requirements.

Hydraulic equipment and similar refinements would have to be sacrificed for simplicity and low price. In most cases the farmer does not have the productive possibilities to enable him to capitalize on his time at a high figure, but he is interested in a good substitute for a team of horses or mules.

The tractor by itself would not find a big market. A wide assortment of simple and readily attached tools would be essential to make the venture practical and appealing to the buyer. A "package" of tractor and perhaps six of these tools could be loaded on a trailer for staging demonstrations of this "40-acre" economy line.

3 Obviously, the market for such a tractor and some of the equipment would reach beyond the small farm. This would make a practical outfit on larger farms for hauling wagons and for a variety of light work. In fact, it might fit some industrial jobs.

The introduction of such a line of machinery would find wide interest and support because much publicity has been focused on this group of landowners.

The attempts that have been made by at least two prominent manufacturers to meet these requirements have not failed, but they have fallen short, more by lack of selling than by lack of engineering.

First we have to sell the idea that we can meet the mechanical requirements and income limitations of this type of farm.

Where the engineering has failed has been by way of too much refinement resulting in costs that are beyond this market.

Various recent developments of methods and materials, including air-cooled engines, V-belt drives, etc., may suggest some new approaches to the type of engineering we have in mind. Indeed it presents a new challenge for the farm machinery industry.

Unit built by Earthmaster Div., Turner Mfg. Co.

Aids for Determining Runoff Probability

This article is presented in an effort to help the practicing engineer to understand the terminology and symbolism of statistical analysis in regard to hydrometeorological data

Roy G. Andrews

THE literature on the statistical analysis of hydrometeorological data is voluminous. Unfortunately much of it concerns highly complicated statistical theory and makes difficult and tedious reading for the practicing engineer whose academic training in statistical analysis is often neglected. This paper is presented in an effort to assist the practicing engineer to understand the terminology and symbolism of statistical analysis. Five methods are used to compute frequency curves from a single array of data and the results are compared graphically. Methods I, II, IV and V are variations of the theory of extreme values; Method III uses the log-probability law.

Flood frequencies may be computed as an annual series or a partial-duration series. Only the greatest flood in each year is used in the annual series. Where structure design is controlled by the most critical condition, such as the design of a spillway, the annual series should be used. The most frequent objection to the use of the annual flood series is that it uses only one flood in each year. Occasionally, the second highest flood in a year, which the above rule omits, may outrank many annual floods.

The partial-duration series meets this objection by listing all floods above an arbitrary base without regard to the number within any given time period. The floods must, however, be independent events. Considerable care must be exercised in the selection of data to insure the independency of events occurring close together in time. The partial-duration series should be used if the second largest value in the year would affect the design of structures. For instance, the damage caused by flooding sometimes results from the repetition of flood occurrences rather than from a single peak flow. An example is the design of farm drainage in which the damage may be due to the extent of flooding, which may be caused largely by associated peak flows.

With either annual or partial-duration series data, the recurrence interval of a flood may be defined as the average number of years a flood of a certain magnitude will be equaled or exceeded. It should be noted that the definition implies no periodicity. A 10-year flood will be *equaled* or *exceeded* 10 times in 100 years *on the average*, but will not occur at regular 10-year intervals. Two or more floods of that magnitude could occur in one year or in successive years.

The annual and partial-duration series methods give essentially identical results for intervals greater than about 10 years. As most designs are for intervals greater than this it is apparent that, from a practical standpoint, either method is satisfactory, although the simplicity of the annual-flood series makes it attractive. From statistical principles there is a definite relationship between the values in the two series. Since the annual-flood series may be converted readily to a partial-duration series by the use of the graph on Fig. 1 (1)*, this paper will be confined to discussions of the annual-flood series.

Hydrologic data are generally analyzed statistically by computing the plotting positions of observed events, plotting the events at these positions on probability or other special paper, and drawing a smooth curve through the plotted points by eye, or by computing the magnitude of events at the desired recurrence intervals from the equation of a theoretical frequency curve. The variables in the equation of the theoretical frequency curve are computed from observed data.

The computation of plotting positions may follow any number of theories. Foster and Hazen (2) used the equation $T=2N/(2m-1)$ and the subcommittee of the Joint Division Committee on Floods of the ASCE (3) recommends the equation $T=(N+1)/m$, first proposed by Kim-

Paper presented at the annual meeting of the American Society of Agricultural Engineers at Roanoke, Va., June, 1956, on a program arranged by the Soil and Water Division.

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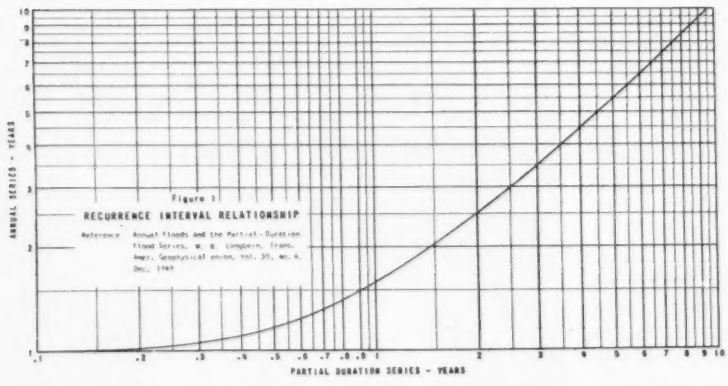

Fig. 1 Annual-flood series may be converted to a partial-duration series on this recurrence interval relationship graph

*Numbers in parentheses refer to the appended references.

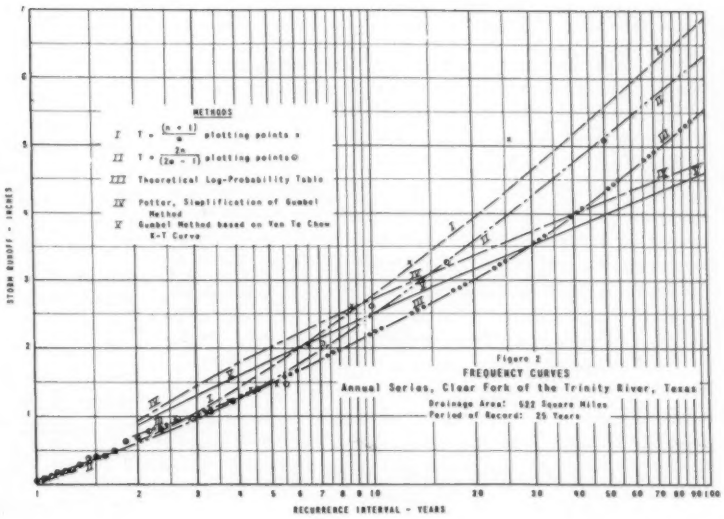
METHODS
I plotting points
II plotting points
III Theoretical Log-Probability Table
IV Potter, Simplification of Gumbel Method
V Gumbel Method based on Yen Te Chow K-T Curve
STORM RUNOFF - INCHES
RECURRENCE INTERVAL - YEARS
Figure 2
FREQUENCY CURVES
Annual Series, Clear Fork of the Trinity River, Texas
Drainage Area: 522 Square Miles
Period of Record: 25 Years

Fig. 2 Plotting position is computed for each flood and plotted on semi-log paper. When data are distributed according to the theory of extreme values, they plot in a straight line on a special plotting paper devised by R. W. Powell (5)

ball (4) in 1946 in which:

T = The frequency, in years, a given flood will be equaled or exceeded —the recurrence interval

N = The number of years of record

m = The order number of the flood

As used in this paper "flood" refers to the total volume of surface runoff from a particular storm event as measured at a stream-gaging station. The methods of analysis are equally applicable to peak discharges.

The volume of the flood flow for the maximum flood in each year of record is tabulated and the floods are numbered consecutively in descending order of magnitude. If the floods are arranged in the tabulation in descending order of magnitude the possibility for error is reduced. The plotting position is computed for each flood by one of the equations and plotted on semi-log plotting paper. (In this paper semi-log plotting paper is used for direct comparisons of methods.) Sample computations for the plotting positions are shown in Table 1 and the curves are designated I and II on Fig. 2. The curves were fitted by eye to the plotted points. A special plotting paper has been devised by R. W. Powell (5). If the data are distributed according to the theory of extreme values, they plot on a straight line on this paper.

The mean, mode, and median values of normally distributed data coincide. When a frequency curve is asymmetrical it is said to be skewed and these values are separated. The skewed type of curve is typical of many hydrologic data. However, the logarithms of the data are often normally distributed.

The log-probability law was first studied by Galton (6) in 1875 and is sometimes known as the law of Galton. Hazen (1) developed a method of computing frequency

TABLE 1. COMPUTATIONS FOR PLOTTING POSITIONS CLEAR FORK OF THE TRINITY RIVER, TEXAS

Water year	Maximum annual storm period runoff (inches)	Rank m	Recurrence interval in years	
			Method I $T=(N+1)/m$	Method II $T=2N/(2m-1)$
1949	5.09	1	26.0	50.0
1942	3.27	2	13.0	16.67
1935	2.63	3	8.67	10.00
1945	2.07	4	6.50	7.14
1948	1.48	5	5.20	5.56
1932	1.42	6	4.33	4.55
1938	1.23	7	3.71	3.85
1940	1.07	8	3.25	3.33
1930	0.97	9	2.89	2.94
1936	0.97	10	2.60	2.63
1941	0.84	11	2.36	2.38
1946	0.80	12	2.17	2.17
1950	0.73	13	2.00	2.00
1944	0.66	14	1.86	1.85
1943	0.51	15	1.73	1.72
1933	0.44	16	1.62	1.61
1951	0.42	17	1.53	1.52
1929	0.39	18	1.44	1.43
1947	0.29	19	1.37	1.35
1931	0.23	20	1.30	1.28
1937	0.21	21	1.24	1.22
1939	0.18	22	1.18	1.16
1952	0.13	23	1.13	1.11
1934	0.08	24	1.08	1.06
1953	0.06	25	1.04	1.02

N=25 years

TABLE 2. COMPUTATION OF COEFFICIENT OF VARIATION CLEAR FORK OF THE TRINITY RIVER AT FORT WORTH, TEXAS

Water year x	Runoff, inches y	y^2
1929	0.39	0.152
1930	0.97	0.941
1931	0.23	0.053
1932	1.42	2.016
1933	0.44	0.194
1934	0.08	0.007
1935	2.63	6.917
1937	0.21	0.044
1936	0.97	0.941
1938	1.23	1.513
1939	0.18	0.032
1940	1.07	1.145
1941	0.84	0.706
1942	3.27	10.693
1943	0.51	0.260
1944	0.66	0.436
1945	2.07	4.285
1946	0.80	0.640
1947	0.29	0.084
1948	1.48	2.190
1949	5.09	25.908
1950	0.73	0.533
1951	0.42	0.176
1952	0.13	0.017
1953	0.06	0.004
$\Sigma y = 26.17$		$\Sigma y^2 = 59.886$

$N = 25$ years

Methodology

$$C_v = \frac{\sqrt{N \Sigma y^2 - (\Sigma y)^2}}{\Sigma y} \quad (11)^*$$

C_v = Coefficient of variation.

N = Number of years record.

y = Maximum storm period runoff in the year, gaged.

$\Sigma y = 26.17$

$\Sigma y^2 = 59.886$

$$\bar{y} = \frac{\Sigma y}{N} = 1.0468$$

$N \Sigma y^2 = 1497.15$

$$C_v = \frac{\sqrt{1497.15 - 684.87}}{26.17}$$

$$C_v = \frac{28.50}{26.17} = 1.0890$$

*See appended reference.

curves graphically by a series of empirically determined log-probability frequency factors. Chow (7) computed a table of theoretically correct log-probability frequency factors for a range of skew coefficients from 0.0 to 5.0.

To compute a theoretical frequency curve from hydrologic data based on the log-probability law the greatest storm runoff in each year is tabulated as the dependent variable, y, as shown in Table 2, and the coefficient of variation, C_v, is computed from the data as indicated on that table. The theoretical log-probability frequency factors, K, corresponding to the coefficient of variation and the desired recurrence intervals, are obtained from Table 3 published by Chow (7) and substituted in the equation

$$y_c = \overline{y}(KC_v + 1)$$

in which:

y_c = Computed plotting point on theoretical curve
$\overline{y}$ = Mean value of observed data
K = Theoretical log-probability frequency factor
C_v = Coefficient of variation

The value of y may be computed for a particular frequency desired or for a series of frequencies as shown by the computations under Method III, Table 4, and plotted to describe the frequency curve designated as III on Fig. 2, This curve plots on a straight line on log-probability plotting paper developed by Hazen.

The theory of extreme values which was introduced by Fisher and Tippett (8) in 1928 and applied to the frequency distribution of hydrologic data by Gumbel (9) in 1941 postulates 1.139 for skewness. Gumbel (10) has written that; "this does not mean that every river with floods that can be analyzed by the theory of extreme values ought to have this skewness independent of the length of the record. The statistical meaning of the statement is instead: If we have a sufficiently large number of observed floods for each stream, the value of skewness should be normally distributed about the mean of 1.139." Data from individual streams which have a coefficient of variation, C_v, at the variance with 0.364 will not be represented exactly by a curve computed by the theory of extreme values; however, it is assumed that if the record were sufficiently long and the sample homogeneous the theory would be applicable.

The computation of a theoretical frequency curve by the theory of extreme values is quite similar to the computations for a curve by the log-probability law in that the coefficient of variation is used as the principal parameter. Potter (11) simplified Gumbel's method by developing a family of empirical curves relating the coefficient of variation, C_v, to the ratio of the plotting position, y_c, to the mean y, $\overline{y}$. Fig. 3 is a reproduction of a portion of this relationship. To compute the value of an event for a specific frequency the chart is

TABLE 3. THEORETICAL LOG-PROBABILITY FREQUENCY FACTORS*

Coefficient of skew	Probability at mean	Probability in percentage Equal to or greater than the given variate 99	95	80	50	20	5	1	0.1	0.01	Corresponding coefficient of variation
		—	—	—	—	+	+	+	+	+	
0	50.0	2.33	1.65	0.84	0	0.84	1.64	2.33	3.09	3.72	0
0.1	49.3	2.25	1.62	0.85	0.02	0.84	1.67	2.40	3.22	3.95	0.033
0.2	48.7	2.18	1.59	0:85	0.04	0.83	1.70	2.47	3.39	4.18	0.067
0.3	48.0	2.11	1.56	0.85	0.06	0.82	1.72	2.55	3.56	4.42	0.100
0.4	47.3	2.04	1.53	0.85	0.07	0.81	1.75	2.62	3.72	4.70	0.136
0.5	46.7	1.98	1.49	0.86	0.09	0.80	1.77	2.70	3.88	4.96	0.166
0.6	46.1	1.91	1.46	0.85	0.10	0.79	1.79	2.77	4.05	5.24	0.197
0.7	45.5	1.85	1.43	0.85	0.11	0.78	1.81	2.84	4.21	5.52	0.230
0.8	44.9	1.79	1.40	0.84	0.13	0.77	1.82	2.90	4.37	5.81	0.262
0.9	44.2	1.74	1.37	0.84	0.14	0.76	1.84	2.97	4.55	6.11	0.292
1.0	43.7	1.68	1.34	0.84	0.15	0.75	1.85	3.03	4.72	6.40	0.324
1.1	43.2	1.63	1.31	0.83	0.16	0.73	1.86	3.09	4.87	6.71	0.351
1.2	42.7	1.58	1.29	0.82	0.17	0.72	1.87	3.15	5.04	7.02	0.381
1.3	42.2	1.54	1.26	0.82	0.18	0.71	1.88	3.21	5.19	7.31	0.409
1.4	41.7	1.49	1.23	0.81	0.19	0.69	1.88	3.26	5.35	7.62	0.436
1.5	41.3	1.45	1.21	0.81	0.20	0.68	1.89	3.31	5.51	7.92	0.462
1.6	40.8	1.41	1.18	0.80	0.21	0.67	1.89	3.36	5.66	8.26	0.490
1.7	40.4	1.38	1.16	0.79	0.22	0.65	1.89	3.40	5.80	8.58	0.517
1.8	40.0	1.34	1.14	0.78	0.22	0.64	1.89	3.44	5.96	8.88	0.544
1.9	39.6	1.31	1.12	0.78	0.23	0.63	1.89	3.48	6.10	9.20	0.570
2.0	39.2	1.28	1.10	0.77	0.24	0.61	1.89	3.52	6.25	9.51	0.596
2.1	38.8	1.25	1.08	0.76	0.24	0.60	1.89	3.55	6.39	9.79	0.620
2.2	38.4	1.22	1.06	0.76	0.25	0.59	1.89	3.59	6.51	10.12	0.643
2.3	38.1	1.20	1.04	0.75	0.25	0.58	1.88	3.62	6.65	10.43	0.667
2.4	37.7	1.17	1.02	0.74	0.26	0.57	1.88	3.65	6.77	10.72	0.691
2.5	37.4	1.15	1.00	0.74	0.26	0.56	1.88	3.67	6.90	10.95	0.713
2.6	37.1	1.12	0.99	0.73	0.26	0.55	1.87	3.70	7.02	11.25	0.734
2.7	36.8	1.10	0.97	0.72	0.27	0.54	1.87	3.72	7.13	11.55	0.755
2.8	36.6	1.08	0.96	0.72	0.27	0.53	1.86	3.74	7.25	11.80	0.776
2.9	36.3	1.06	0.95	0.71	0.27	0.52	1.86	3.76	7.36	12.10	0.796
3.0	36.0	1.04	0.93	0.71	0.28	0.51	1.85	3.78	7.47	12.36	0.818
3.2	35.5	1.01	0.90	0.69	0.28	0.49	1.84	3.81	7.65	12.85	0.857
3.4	35.1	0.98	0.88	0.68	0.29	0.47	1.83	3.84	7.84	13.36	0.895
3.6	34.7	0.95	0.86	0.67	0.29	0.46	1.81	3.87	8.00	13.83	0.930
3.8	34.2	0.92	0.84	0.66	0.29	0.44	1.80	3.89	8.16	14.23	0.966
4.0	33.9	0.90	0.82	0.65	0.29	0.42	1.78	3.91	8.30	14.70	1.000
4.5	33.0	0.84	0.78	0.63	0.30	0.39	1.75	3.93	8.60	15.62	1.081
5.0	32.3	0.80	0.74	0.62	0.30	0.37	1.71	3.95	8.86	16.45	1.155

*From "Log-Probability Law and Its Engineering Applications" by Ven Te Chow, ASCE Proceedings, Vol. 80, Separate No. 536, November, 1954.

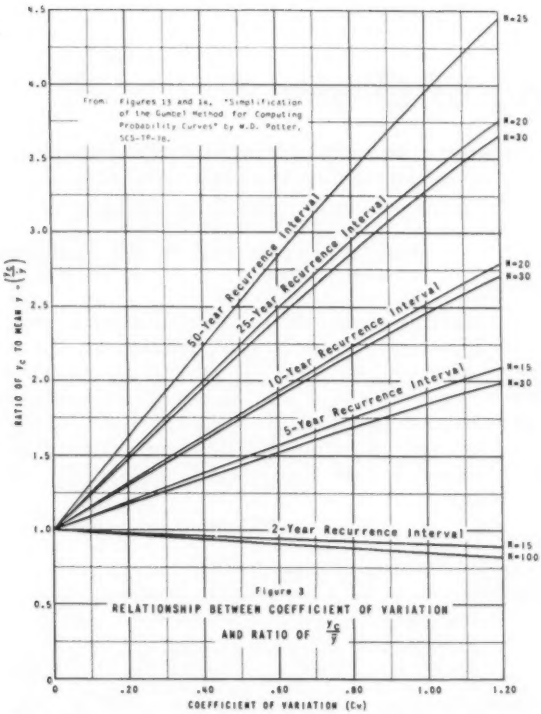

Fig. 3 Simplication of the Gumbel method for computing probability curves by developing a family of empierical curves

entered with the C_v computed in Table 1, and the ratio of y_c to $\bar{y}$ for the frequency and number of years of record, N, is obtained. This value is multiplied by $\bar{y}$ to obtain the magnitude of the event for the desired frequency. The computations are shown under Method IV, Table 4, and the frequency curve described by the computed values is designated as IV on Fig. 2.

Chow (12) showed that the Gumbel method could be expressed by the equation $y_c/\bar{y}=1+KC_v$ and computed a curve relating the frequency factor, K, to the recurrence interval, T. This curve is reproduced as Fig. 4. To compute a theoretical extreme-value frequency curve enter the curve on Fig. 4 with the desired frequency and find the corresponding K value. Insert this value and the value of $\bar{y}$ and C_v computed on Table 1 in the equation $y_c=\bar{y}(KC_v+1)$ and compute the value of the event corresponding to the desired frequency. The computations are shown under Method V, Table 4 and the frequency curve described by the computed values is designated as V on Fig. 2.

Although there is little agreement among engineers as to which method is the most accurate to use in computing the frequency of hydrologic events there is unanimity of opinion on numerous cautions that should be used. To be strictly applicable to frequency analysis the events must be completely independent and the sample homogeneous, that is, be representative of a long period of record. Since the actual record will not meet either of these principles completely some error should be expected. Extrapolation beyond the period of record should be done with the utmost caution. When possible, frequency curves should be com-

(Continued on page 178)

TABLE 4. ANNUAL FLOOD FREQUENCY LINES BY THEORETICAL METHODS CLEAR FORK OF THE TRINITY RIVER, TEXAS

Where $C_v=1.089$ and $\bar{y}=1.0468$

Recurrence interval (years)	Method III* Theoretical Log-probability		Method IV† Potter, simplification of Gumbel		Method V‡ Gumbel, based on Ven Te Chow K-T curve	
	Frequency factor	Plotting position		Plotting position		Plotting position
	K§	y_c	$\frac{y_c\|\|}{\bar{y}}$	y_c	K#	y_c
2	−0.30	0.70	0.90	0.94	−0.15	0.88
5	0.39	1.49	1.93	2.02	0.70	1.84
10			2.62	2.74	1.28	2.51
20	1.75	3.04				
25			3.50	3.66	2.03	3.36
50			4.19	4.39		
100	3.93	5.53			3.13	4.62

Equations:

*$y_c=(KC_e+1)\bar{y}$

†$y_c=y(y_c/\bar{y})$

‡$y_c=(KC_e+1)\bar{y}$

§See Table 3

||See Fig. 3

#See Fig. 4

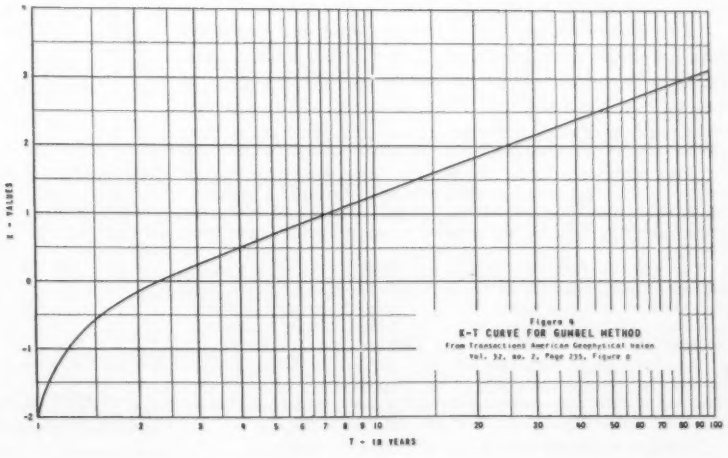
K - VALUES
T - IN YEARS
Figure 4
K-T CURVE FOR GUMBEL METHOD
From Transactions American Geophysical Union
Vol. 32, no. 2, Page 235, Figure 6

Fig. 4 The Gumbel method expressed by the equation $y_c/\bar{y}=1+KC_v$ and plotted in a *K-T curve*

Predicting Pressure Drop in Pneumatic Conveying of Grains

In this paper is presented a theoretical analysis from which is developed an equation which will enable the design engineer to calculate one of three components of pressure drop in a pneumatic conveying system

Jack W. Crane and W. M. Carleton
Assoc. Member ASAE Member ASAE

FOR many years the problem of homogeneous fluid flow has been investigated, both experimentally and analytically, in a very thorough manner. However, little attention has been given to the pneumatic conveying of solids. Pneumatic conveying, as discussed in this paper, will have reference to a system in which the particles receive 100 percent of their energy from the conveying air stream and do not come in contact with the blower blades. Systems of this type have proven popular in European countries. However, in the United States, farm conveying systems have been primarily of the impeller type. This type has one serious disadvantage when conveying material which is susceptible to injury by impact. Since most of the energy is imparted to the particle by the impeller wheel, the particle has no immediate source of energy to draw upon to replenish that lost through the piping system. This means that the transporting distance is limited by the energy imparted to the particle. If such a system contains bends or long lengths of horizontal pipe, where energy losses are great, the maximum transporting distance will be short, unless it is possible to operate the impeller wheel at relatively high speeds.

In a pneumatic conveying system it is important that the design engineer be able to calculate the pressure drop due to the solid material to be conveyed, since this is the criterion used to select the size of blower needed. The purpose of this paper is to present a theoretical analysis leading to equations which can be used by the design engineer to predict the pressure drop in a straight length of pipe after steady-state conditions prevail, that is particle acceleration equals zero, dependent upon *(a)* material being conveyed, *(b)* solid flow rate, *(c)* air velocity, *(d)* pipe diameter, *(e)* pipe length, and *(f)* pipe inclination. Losses at bends and during the acceleration period are not considered in this paper.

The theoretical analysis to be presented will use as its base the initial assumptions set forth by Pinkus (6)* who presented a convincing theory for the case of sand particles flowing in a horizontal pipe. Pinkus' theory will be adapted to agricultural grains and extended to include pipes of any inclination, thus making the resultant equations of more value to the design engineer. Other investigators, such as Segler (7), Hariu and Molstad (5), and Vogt and White (8), have studied pressure drops in vertical and horizontal pipes using different methods of attack. To the authors' knowledge, none has presented a sound theoretical analysis which encompassed the entire range of pipe angles from 0 to 90 deg.

Theory

Due to the complex nature of the system to be analyzed, it was necessary to make the following simplifying assumptions before proceeding with the pressure-drop analysis:

- The component of velocity perpendicular to the pipe wall will be small relative to that parallel to the wall.
- The total pressure drop along any section of pipe, after steady-state conditions ($a_p=0$) are reached, is composed of three factors, these being, *(a)* that due to the air alone (this is assumed to remain constant with or without particles in the air stream), *(b)* that due to the particles striking each other and the pipe wall, and *(c)* that due to the static head of the solids.
- The coefficient of resistance, as applied to freely falling bodies, can be applied to particles moving in an airstream. This expression will be used to calculate the force exerted on the particles by the air stream.
- A friction equation of the Fanning or Darcy-Weisback type will account for energy loss due to impact between the individual particles and the pipe wall.

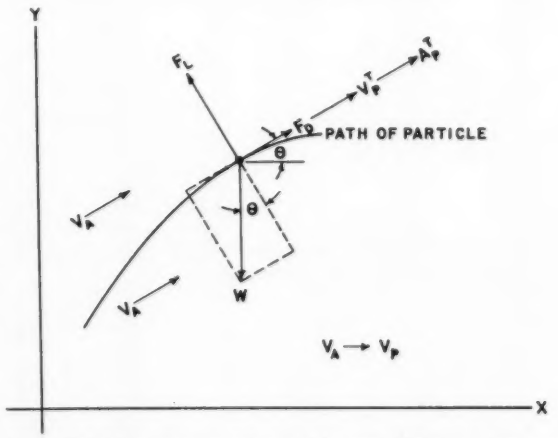

Fig. 1 Free-body diagram of a single particle being given an upward acceleration due to an airstream, the direction of which is tangent to the path of motion

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The authors—JACK W. CRANE and WALTER M. CARLETON—are, respectively, engineer in research and development, New Holland Machine Co. and former graduate research assistant at Michigan State University, and assistant chief, AERB, USDA, and former professor of agricultural engineering, Michigan State University.

Acknowledgment: The authors wish to express their appreciation for the financial assistance of the New Holland Machine Co. and to H. F. McColly, professor of agricultural engineering, Michigan State University for his assistance during this project.

*Numbers in parentheses refer to the appended references.

Fig. 2 Test apparatus, with a pipe inclination of 90 deg, used in the MSU study of pressure drop in pneumatic conveying of grains

The equation of motion is developed from the free body diagram of a single particle shown in Fig. 1. Applying Newton's Law ($\Sigma F = ma$) to the system in this figure and summing the forces in the tangential direction gives:

$$\Sigma F_{(tan)} = F_D - W\left(\frac{\rho_p - \rho_a}{\rho_p}\right) \text{SIN } \theta = ma \quad [1]$$

The drag force (F_D), as defined by Goldstein (4) for free falling spheres, is equal to $\rho_a V^2 CA/2g$. Dallavalle (3) has presented an experimental curve of coefficient of resistance (C) versus Reynolds number (RN) for spheres. This curve can be closely approximated for the RN between 10^3 and $10^{4.5}$ by the following expression:

$$C = 0.4 + \frac{40}{RN}$$

Since both the air stream and the particles in a pneumatic conveying system are moving, it is necessary to substitute the relative velocity ($v_a - v_s$) for v in the previous expression. Equation [1] now becomes

$$\frac{\rho_a (v_a - v_s)^2}{2g} C A_p - mg\left(\frac{\rho_p - \rho_a}{\rho_p}\right) \text{SIN } \theta = m \frac{dv_s}{dt} \quad [2]$$

This equation would hold for one particle in an airstream, but if several particles are simultaneously in the stream, an additional term must be included to account for energy lost due to collisions with other particles. In addition, if the particles are enclosed in a pipe, this term must account for losses due to sliding on the pipe wall.

Following the suggestions of other investigators, the Darcy-Weisback friction equation as given in (6) will be added to account for these extra losses encountered in actual pneumatic transporting systems:

$$H = \frac{f_s L_D v_s^2}{2Dg}$$

By recognizing that ($L_D \rho_{ds} A_p = W$ and that (ΔP) $A_p = F$, the above equation can be rewritten as:

$$F = \frac{f_s v_s^2 m}{2D}$$

Adding this term to those of equation [2] gives the complete differential equation of motion for the system:

$$\frac{dv_s}{dt} = \frac{\rho_a (v_a - v_s)^2}{2mg} C A_p - g\left(\frac{\rho_s - \rho_a}{\rho_s}\right) \text{SIN } \theta - \frac{f_s v_s^2}{2D} \quad [3]$$

Primary Symbols and Subscripts

d, diameter of particle (ft)
D, diameter of duct (ft)
H, frictional head (ft of water)
h, frictional head (inches of water)
f, friction factor (dimensionless)
ρ, density (lb/ft³)
ρ_{ds}, density of dispersed solids (lb/ft³ of pipe)
V, volume (ft³)
μ, absolute viscosity (lb/ft sec)
v, velocity (ft/sec)
t, time (sec)
s, distance (ft)
RN, Reynolds number (dimensionless)
P, pressure (lb/ft²)
N, quantity or number
m, mass of particle (lb sec²/ft)
L, length (ft)
G_s, mass flow of solids (lb/ft²sec)
g, gravitational acceleration (ft/sec²)
W, weight (lb)
a, acceleration (ft/sec²)
F_L, lift force (lb)
F_D drag force (lb)
θ, pipe angle from the horizontal (deg)
A, area (ft²)
Subscripts:
a, air
D, duct
ds, dispersed solids
sh, static head
sf, solids friction
s, solids
p, particle

. . . Pressure Drop in Grains

When steady-state conditions prevail ($d\,v_s/dt=0$), equation [3] can be rewritten in the following form:

$$\frac{\rho_a(v_a-v_s)^2}{2g}CA_p = mg\left(\frac{\rho_s-\rho_a}{\rho_s}\right)\text{SIN}\,\theta + \frac{f_s v_s^2 m}{2D} \quad [4]$$

Since for grains the term $(\rho_s-\rho_a)/\rho_s$ is very nearly unity, it will be neglected in the remaining pressure-drop calculations.

It can be seen from the force balance in equation [4] that the energy loss due to the solids' friction plus that due to the static head will be equal to that supplied by the drag correlation.

Converting each of the force terms in equation [4] into equivalent expressions for pressure drop per unit of mass flow by use of $G_s=\rho_{ds}v_s$, results in the following expression:

- For the impact between the particles and the tube wall the Darcy-Weisback friction equation gives

$$\frac{\Delta H_{fs}}{L\,G_s} = \frac{f_s\,v_s}{2Dg\rho_{H_2O}}$$

- For the static head expression

$$\frac{\Delta H_{sh}}{L\,G_s} = \frac{\text{SIN}\,\theta}{\rho_{H_2O}\,v_s}$$

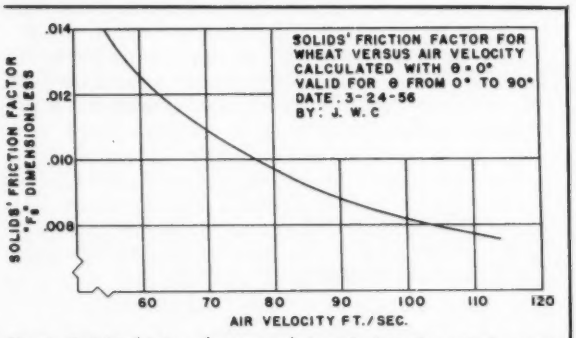


Fig. 3 Solids' friction factor used to calculate theoretical curves shown in Figs. 4, 5, 6 and 7 (Below) Pressure drops caused by solid phase for various pipe angles

- For the drag correlation

$$F_{(\text{per particle})} = \frac{\rho_a C A_p (v_a-v_s)^2}{2g}$$

the number of particles present in L feet of pipe will be

$$N = \frac{G_s\,A_D\,L_D}{v_s\,V_p\,\rho_p}$$

So the total force exerted on the solids in L feet of pipe is

$$F\,(\text{total}) = F\,(\text{per particle}) \times N$$

Changing to drop per unit of mass flow,

$$\frac{\Delta H_s}{L_D G_s} = \frac{\rho_a C A_p (v_a-v_s)^2}{\rho_{H_2O}\,2g\,v_s V_p \rho_p}$$

Substituting these three equivalent expressions into the force equation [4] gives the following equation:

$$\frac{\rho_a C A_p (v_a-v_s)^2}{\rho_{H_2O}\,2g v_s V_p \rho_p} = \frac{\text{SIN}\,\theta}{\rho_{H_2O}\,v_s} + \frac{f_s\,v_s}{2Dg\rho_{H_2O}}$$

Solving this equation for f_s gives the following:

$$f_s = \frac{D\left[\rho_a C A_p (v_a-v_s)^2 - 2g V_p \rho_p \text{SIN}\,\theta\right]}{V_p \rho_p v_s^2} \quad [5]$$

This expression can be used to determine f_s experimentally from the observed data.

As previously mentioned, the total head loss for a given length of pipe (assuming steady-state flow exists) is composed of three factors:

$$\triangle H = \triangle H_{sf} + \triangle H_{sh} + \triangle H_a$$

If the steady-state condition has not been attained, another term must be added to account for the pressure loss during the acceleration period. Since this loss is not considered in this analysis, the complete expression for pressure drop, with steady-state flow, is as follows:

$$\Delta H = \frac{f_s\,v_s L_D G_s}{2Dg\,\rho_{H_2O}} + \frac{G_s L_D}{v_s \rho_{H_2O}}\text{SIN}\,\theta + \frac{f_a L_D v_a^2 \rho_a}{2Dg\,\rho_{H_2O}} \quad [6]$$

Fig. 4 0-deg Pipe Angle

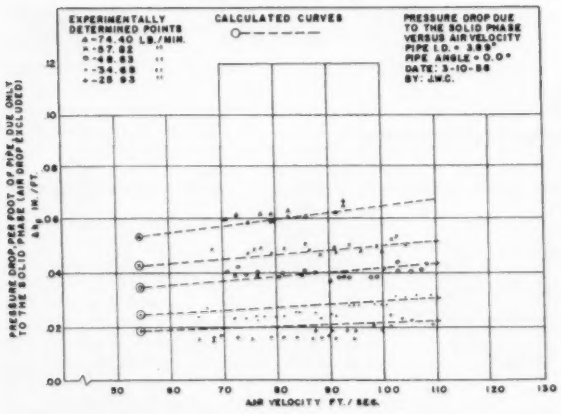
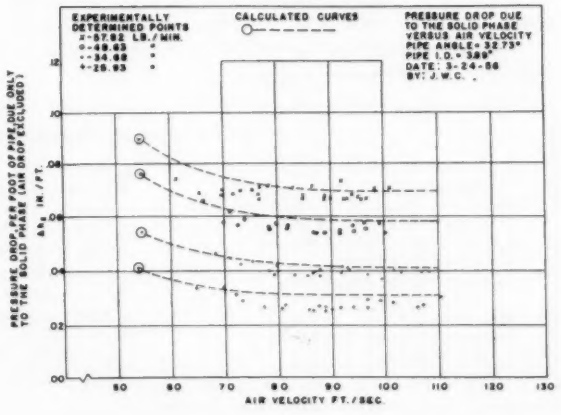


Fig. 5 32.73-deg Pipe Angle



The experimentally determined value of the solids' friction factor is f_s and the value of the Darcy-Weisback friction factor for the flow of air through pipes is f_a.

Assuming that the solids' friction factor (f_s) has been determined experimentally, the only other unknown preventing the practical use of equation [6] is that of the velocity of the solids. The differential equation of motion [3] will now be solved for v_s in terms of the other variables. Equation [3] is simplified by letting

$$r = \frac{A_p \rho_a}{2 m g} \qquad y = \frac{f_s}{2D} \qquad z = g \sin\theta \qquad C = 0.4 + \frac{40}{RN}$$

$$RN = x(v_a - v_s) \quad \text{where} \quad x = \frac{d \rho_a}{\mu_a}$$

Substitution in equation [3] and factoring the variable v_s from the resulting expression yields the following equation:

$$\frac{dv_s}{dt} = v_s^2(0.4r - y) + v_s(-0.8 r v_a - \frac{r}{x}40) + 0.4 r v_a^2 + \frac{r}{x}40 v_a - z$$

By recognizing that the only variables in the above equation are v_s and t, it can be reduced to a first-order, first-degree differential equation in which the variables are separable. This is evident by making the following substitution:

$$C_1 = 0.4r - y$$

$$C_2 = -0.8 r v_a - 40\frac{r}{x}$$

$$C_3 = 0.4 r v_a^2 + 40\frac{r}{x} v_a - z$$

$$dt = \frac{dv_s}{C_1 v_s^2 + C_2 v_s + C_3}$$

The solution to the above equation is

$$t = \frac{1}{\sqrt{Q}} \ln \frac{2C_1 v_s + C_2 - \sqrt{Q}}{2C_1 v_s + C_2 + \sqrt{Q}} + C$$

where $Q = C_2^2 - 4 C_3 C_1$.

Since the initial conditions are $v_s = 0$, when $t = 0$, the constant of integration, C is equal to

$$C = -\frac{1}{\sqrt{Q}} \ln \frac{C_2 - \sqrt{Q}}{C_2 + \sqrt{Q}}$$

Substituting this in the equation for t and solving for v_s gives

$$v_s = \frac{Q - C_2^2 + C_2^2 e^{-t\sqrt{Q}} - Q e^{-t\sqrt{Q}} + 4C_1 v_s \sqrt{Q}\, e^{-t\sqrt{Q}}}{2C_1 C_2 - 2C_1\sqrt{Q}}$$

The terminal velocity which particles will reach can now be determined by letting $t \to \infty$ in the previous expression. This yields the resultant equation for v_s.

$$v_s = \frac{-2C_3}{C_2 - \sqrt{C_2^2 - 4C_1 C_3}} \qquad [7]$$

The constants for the above equation are:

$$C_1 = \frac{0.2 A_p \rho_a}{mg} - \frac{f_s}{2D}$$

$$C_2 = \frac{-0.4 A_p \rho_a v_a}{mg} - \frac{20 A_p \mu_a}{mgd}$$

$$C_3 = \frac{0.2 A_p \rho_a v_a^2}{mg} + \frac{20 A_p \mu_a v_a}{mgd} - g \sin\theta$$

It is now possible for the engineer using equations [6] and [7] to calculate the pressure drop in any straight section of pipe, where steady state conditions prevail, knowing only f_s, f_a, and the design specifications.

Apparatus

With the above theoretical analysis completed, it was then necessary to construct a test apparatus which could be used to prove or disprove the equations that had been derived. The individual measurements which had to be made during a test cycle consumed considerable time. Therefore, it was felt that a continuous system would have a distinct advantage over the type in which it was necessary to recharge the hopper manually. It was also necessary to design the system so that the test section could be adjusted to any angle between 0 and 90 deg. Fig. 2 shows the apparatus with the

(Continued on page 180)

Fig. 6 62.5-deg Pipe Angle

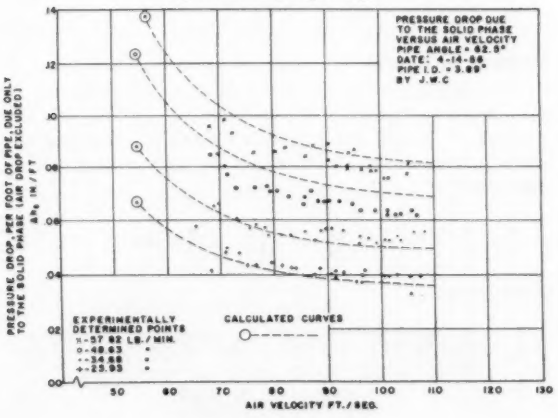
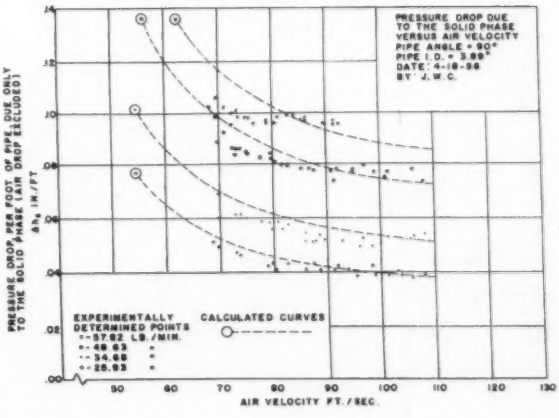

PRESSURE DROP DUE TO THE SOLID PHASE VERSUS AIR VELOCITY
PIPE ANGLE = 62.5°
DATE: 4-14-56
PIPE I.D. = 3.89"
BY J.W.C
PRESSURE DROP, PER FOOT OF PIPE, DUE ONLY TO THE SOLID PHASE (AIR DROP EXCLUDED)
Δp_s IN./FT
EXPERIMENTALLY DETERMINED POINTS
CALCULATED CURVES
AIR VELOCITY FT./SEC.

Fig. 7 90-deg Pipe Angle


PRESSURE DROP DUE TO THE SOLID PHASE VERSUS AIR VELOCITY
PIPE ANGLE = 90°
PIPE I.D. = 3.89"
DATE: 4-10-56
BY J.W.C.
PRESSURE DROP, PER FOOT OF PIPE, DUE ONLY TO THE SOLID PHASE (AIR DROP EXCLUDED)
Δp_s IN./FT
EXPERIMENTALLY DETERMINED POINTS
CALCULATED CURVES
AIR VELOCITY FT./SEC.

Properties of Straight-Sided Spline Sections

R. Bruce Hopkins
Member ASAE

SHAFTS with multiple integral keys, called splines, are used frequently for power transmission applications, such as sliding-gear transmissions and tractor power take-offs. Spline shafts are well adapted to mass production since the splines can be hobbed on a shaft more economically and with less error in spacing than by milling out the spaces between the splines individually. All the splines in a female part are produced by a single pass of a broach.

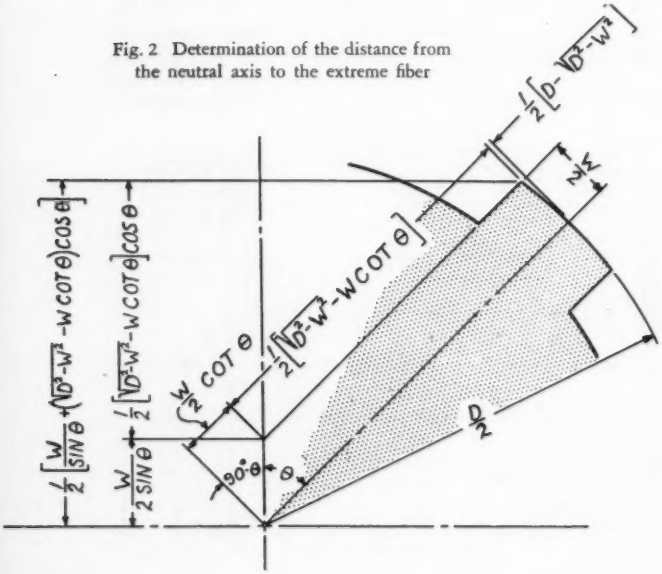
The stress in a spline shaft subject to a bending load depends upon the section modulus; the deflection is dependent upon the moment of inertia. It is often necessary to select a spline shaft of a suitable size to limit the deflection to a reasonable value. A common practice among design engineers is to compute the moment of inertia assuming it to be the same as for a solid shaft of a diameter intermediate between the root and outside diameters. The accuracy of such calculations is dependent upon the designers' ability to estimate a correct mean diameter. The use of correct values would permit more precise design calculations. The methods of calculating the properties — cross-sectional area, moment of inertia, and section modulus—of such sections are studied by undergraduate engineers through courses in integral calculus and mechanics. Standard texts (3, 6)* on the subject explain the methods of calculation.

Paper prepared expressly for AGRICULTURAL ENGINEERING.

*Numbers in parentheses refer to the appended references.

The author — R. BRUCE HOPKINS — is an engineer at the John Deere Waterloo Tractor Works, Waterloo, Iowa.

Fig. 2 Determination of the distance from the neutral axis to the extreme fiber



The analysis of the properties of spline sections can be approached either by considering the shaft as a round section with portions removed or as a smaller round section with the splines added. The latter method was selected because the integrals are relatively simple.

Symbols

A = area
d = root diameter of shaft
D = outside diameter of shaft
$\bar{I}$ = moment of inertia about a centroidal axis
I = moment of inertia about an axis parallel to a centroidal axis
W = width of spline
Z = section modulus

Subscript s refers to a property of the spline section.

Subscripts x and y refer to properties about the horizontal and vertical axes, respectively.

Cross-Sectional Area

The area of the cross section is the sum of the root area, $\pi d^2/4$, and the area of the spline sections. The equation of the root circle is $x^2+y^2=d^2/4$ and the equation of the circle forming the outside diameter is $x^2+y^2=D^2/4$ with the axes selected as shown in Fig. 1. The cross-sectional area of one spline is found as follows:

$$A_s = \int y\,dx = 2\int_0^{\frac{W}{2}} \left(\sqrt{\frac{D^2}{4}-x^2} - \sqrt{\frac{d^2}{4}-x^2}\right) dx \quad [1]$$

which when integrated becomes

$$A_s = \frac{1}{4}\left[W\left(\sqrt{D^2-W^2}-\sqrt{d^2-W^2}\right)+D^2\sin^{-1}\frac{W}{D}-d^2\sin^{-1}\frac{W}{d}\right] \quad [2]$$

Moment of Inertia

The moment of inertia of the shaft section is the sum of the moment of inertia of the root section, $\pi d^4/64$, and the moment of inertia of the several splines. Considering the spline section in the relationship to the coordinate axes shown in Fig. 1

$$\bar{I}_{y,s} = \int x^2\,dA = 2\int_0^{\frac{W}{2}} \left(\sqrt{\frac{D^2}{4}-x^2} - \sqrt{\frac{d^2}{4}-x^2}\right) x^2\,dx \quad [3]$$

which becomes

$$\bar{I}_{y,s} = W\left[\frac{1}{32}\left(\sqrt{(d^2-W^2)^3}-\sqrt{(D^2-W^2)^3}\right)+\frac{1}{64}\left(D^2\sqrt{D^2-W^2}-d^2\sqrt{d^2-W^2}\right)\right] + \frac{1}{64}\left(D^4\sin^{-1}\frac{W}{D}-d^4\sin^{-1}\frac{W}{d}\right) \quad [4]$$

The wide use of spline shafts in the agricultural implement industry calls for information on shaft selection with regard to stress and deflection

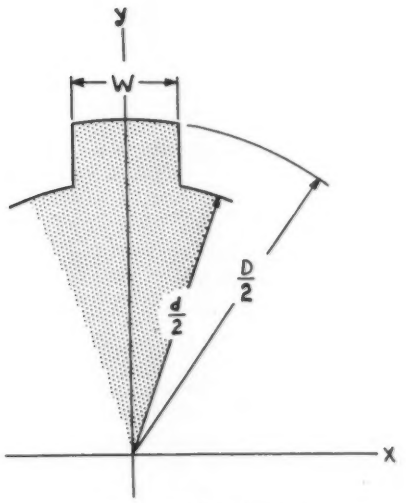


Fig. 1 Sketch of a spline

In a similar manner, $I_{z,s}$ can be established

$$I_{x,s} = \int Y^2 dA = W\left[\frac{1}{96}\left(\sqrt{(D^2-W^2)^3} - \sqrt{(d^2-W^2)^3}\right) + \frac{1}{64}\left(D^2\sqrt{D^2-W^2} - d^2\sqrt{d^2-W^2}\right)\right]$$

$$+\frac{1}{64}\left(D^4 \sin^{-1}\frac{W}{D} - d^4 \sin^{-1}\frac{W}{d}\right) \quad . \quad . \quad [5]$$

Because some of the splines are located on inclined axes, it would normally be necessary to evaluate the moments of inertia about those axes. However, Benford (2) pointed out that for any number of equally-spaced splines greater than two, the total moment of inertia of the splines is equal to one-half the number of splines multiplied by the sum of $I_{z,s}$ and $\bar{I}_{y,s}$. Then for the entire spline shaft section with n splines

$$I = \pi\frac{d^4}{64} + \frac{n}{2}\left(I_{x,s} + \bar{I}_{y,s}\right) \quad . \quad . \quad . \quad [6]$$

It can also be shown that for n greater than two, the moment of inertia is independent of the angular position of the splines with regard to the coordinate axes.

Section Modulus

The magnitude of the section modulus is dependent upon the plane of load application since $Z = I/c$ in which c is the distance from the neutral axis to the extreme fiber. When the load is applied in the plane of a spline, the section

(Continued on page 179)

Fig. 3 Cross-sectional area of splined shafts

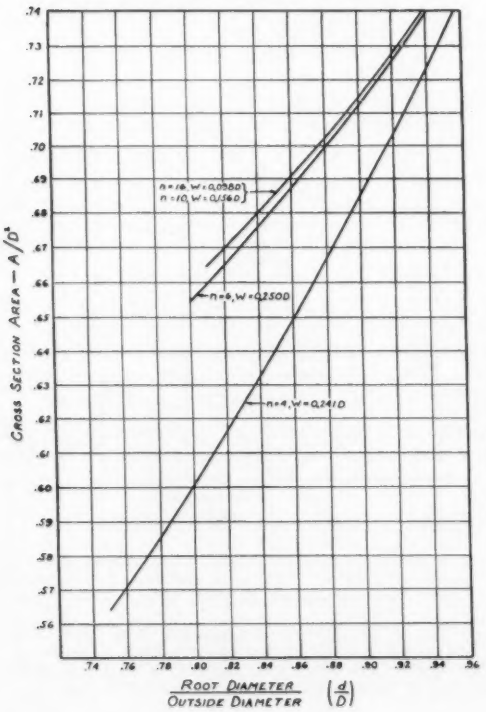
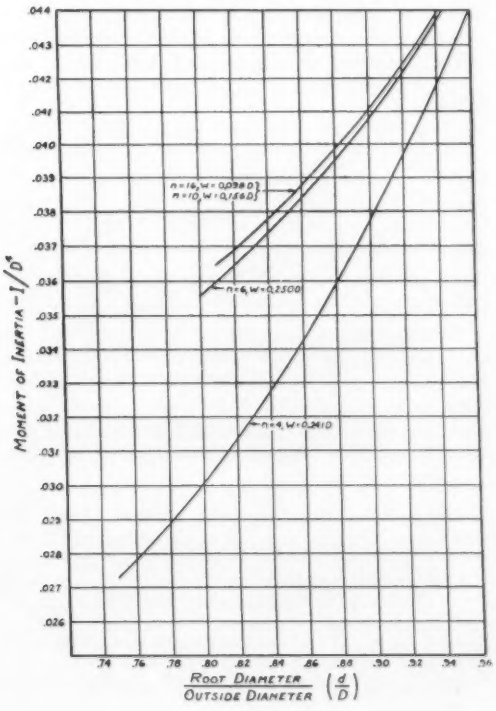


Fig. 4 Moment of inertia of splined shafts



Bolted Plywood Gussets

L. M. Staley and L. W. Neubauer
Assoc. Member ASAE Member ASAE

Because bolted connections are especially desirable in temporary, portable, or prefabricated structures, the authors undertook a series of tests to determine allowable design loads for bolts in plywood, the results of which are reported in this paper.

PLYWOOD has gained widespread acceptance as a versatile building material in the construction industry. Improvements in quality, inherent rigidity and split resistance, large panel size and competitive cost, all combine to make plywood ideally suited for gusset and splice plates on light truss construction.

The choice of fasteners presents a designer with several possibilities, the selection of which may depend upon such factors as availability, cost, location and stress conditions. Timber connectors are essential to efficient design of heavy timber construction, but present methods of plywood manufacture are not suited to sheet thicknesses adequate for optimum usage. Glued joints are very efficient and rigid but require considerable care in fabrication to insure proper coverage with glue. Nailed joints are easy to construct but under some conditions nails will tend to pull, thus weakening the joint. Bolts will provide a less rigid connection than glue but tests indicate that failure consists of gradually crushing wood fibers under the bolt (provided minimum end and edge distances are maintained); hence collapse is not sudden as is the case with glued joints.

Design data are available for plywood gussets with most fastening methods except bolts. Bolted connections are especially desirable in temporary, portable or prefabricated structures. Therefore, a series of tests to determine allowable design loads for bolts in plywood was initiated in 1955 at the University of California at Davis.

Tests

Test specimens were made from exterior grade Douglas fir plywood ½ in and ¾ in thick for gusset plates, and Douglas fir select structural 2x4 as center members. The 2x4 and plywood both initially air dry were stored in the testing room for at least one week before using to permit time for moisture equilibrium. Bolts were ¼, ⅜, ½, ¾ and 1¼ in in diameter, standard square-head machine bolts with a yield point of 45,000 lb per sq in.

Plywood gussets were cut 4x6 in for bolts ½ in diameter and over, and 3x6 in for bolts under ½ in diameter. The 2x4 in center member was 6 in long. These sizes were adequate to develop the full bolt bearing strength of the plywood (4)*. All the gussets used in a series of tests were cut from the same sheet of plywood and matched as closely as possible.

Holes were drilled 1/64 in oversize, with sharpened twist drills. Gussets were bolted on both sides of the center member, and the bolt tightened with light finger pressure. The resulting joints were then tested in compression. This was felt to be a more realistic test than had been used in the past (4). Frictional resistance between the gusset and center member was negligible.

A minimum of three replications was made on each change of variable. Proportional and ultimate limits were picked from load-deflection recorder charts. Results were averaged to obtain a representative value for each set of conditions.

Variables

At least twelve separate variables influence the strength of bolted plywood joints. For purposes of this study only four were investigated. These are

- angle between direction of load and grain of the face ply
- plywood thickness
- bolt diameter
- bolt tension.

Other variables which were eliminated or held constant are

- condition of the bolt hole (1)
- hole clearance
- end and edge distance (4)
- grade and plywood species
- moisture content (2) (3)
- rate of loading (6)
- degree of shear on the bolt
- size of center member.

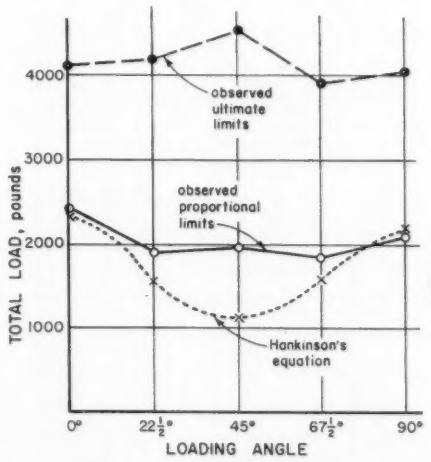


Fig. 1 Variation of proportional and ultimate limit loads with angle of load to the direction of the face ply grain. The use of Hankinson's equation for determining allowable loads at any angle requires a correction in the region from 25 to 65 deg.

Paper prepared expressly for AGRICULTURAL ENGINEERING.

The authors—L. M. STALEY and L. W. NEUBAUER—are, respectively, assistant professor of agricultural engineering, Ontario Agricultural College, and associate professor of agricultural engineering, University of California, (Davis).

*Numbers in parentheses refer to the appended references.

Fig. 2 Plywood bolt-bearing failure showing supporting effect of adjacent fibers. Adjacent plies are also influenced by transfer of stress through the glue

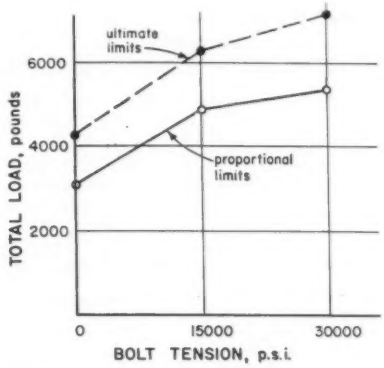


Fig. 3 Variation of joint strength with increase in bolt tension for ½-in gussets and ½-in-diam bolts. Note the rapid increase in joint strength with increased bolt tension up to 15,000 psi

Loading Angle

Fifteen tests were devoted to determining the effect of angle of loading on the strength of joints with ½-in-diam bolts and ½-in plywood gussets.

Fig. 1 shows the variation in load at the proportional and ultimate limits for five loading angles. Hankinson's equation (5) has been applied to individual sheets of veneer and summed to give the results also shown in Fig. 1.

Hankinson's equation is widely accepted as the most reliable means of determining allowable compressive stresses at any angle to the direction of grain. These data indicate, however, that the equation is considerably on the conservative side for loading angles between 25 and 65 deg to the face ply grain.

One possible reason for this lack of agreement is the supporting action of adjacent fibers and plies when loads are at angles other than parallel to the grain. The nature of this assistance is partly due to shear and tension stresses. This sphere of influence is illustrated in Fig. 2. The example also points out the tenacious qualities of plywood. Provided adequate edge and end distances are maintained, failure is a gradual crushing of plywood fibers under the bolt.

For most purposes plywood of nearly balanced design (equal thickness of face plies and cross plies) can be assumed to exhibit equal strength for any loading angle.

Bolt Tension

Tests indicate that tight bolts materially increase the strength of a joint. Bolts (½-in diam) were tightened to a tensile stress of 15,000 and 30,000 psi in ½-in plywood gussets. Heavy steel plate washers were required to distribute the stress and prevent crushing of the plywood.

Results are summarized in Table 1 and illustrated in Fig. 3. The strength of the joint increases rapidly with increased bolt tension. Therefore, if the lumber is known to be dry prior to fabrication, one could allow an extra 1000 lb per bolt due to friction. Then with a basic load of 3000 lb plus 1000 lb due to friction and taking a safety factor of 2, we have a safe design load of 2000 lb per bolt. This is equivalent to an average stress of 4000 psi for fully tightened ½-in-diam bolts in ½-in plywood gussets.

If the joint is likely to experience very damp and dry cycles, no increase in strength due to friction should be allowed. Swelling would cause crushing of the plywood under the washers, then, on drying, shrinkages would reduce the bolt tension and friction.

Tight bolts appear to distribute the load more uniformly between the components of the joint. For example, the bolt holes in gussets and center member are about equally distorted at failure; the bolt has undergone an increase in effective stiffness as pointed out in bolt *(D)*, Fig. 4.

TABLE 1. LOADS SUPPORTED BY JOINTS WITH VARIOUS BOLT TENSIONS

(One-half-inch-diameter bolts and ½-in plywood gussets)

Bolt tensions, psi	Proportional limit, lb	Ultimate limit lb	$K = \frac{\text{Prop limit}}{\text{Ult. limit}}$
0	3030	4250	0.71
15,000	4850	6220	0.78
30,000	5360	7260	0.74
		Average $K = 0.74$	

Bolt Size

The progressive stiffness of the bolts with increasing diameters as shown in Fig. 4 is also in general the main component limiting the elastic range of the joint. This is readily apparent when joint strength at the elastic limit is

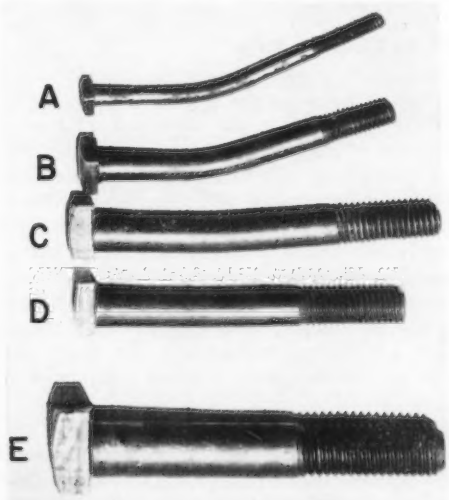


Fig. 4 Bolt stiffness is influenced by length and by diameter as shown (A, ¼ in, to E, ¾ in). Note the increased stiffness by tensioning the bolt D (½ in) as compared to C (½ in).

. . . Bolted Gussets

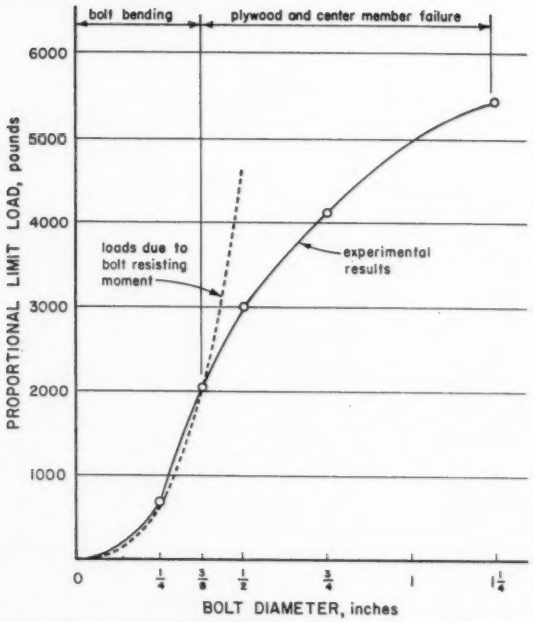


Fig. 5 Total proportional limit load carried by ½-in plywood gussets with various bolt diameters. Joint strength is influenced by the resisting moment of the bolt for diameters less than ½ in. Similar results are obtained with ¾-in gussets but at higher loads for bolts ½ in diameter and over

compared with bolt diameters in Fig. 5. For bolt diameters smaller than ½ in, the joint strength varies as the cube of the bolt diameter indicating the bolt resisting moment influence. Bolts ½-in diameter and over are sufficiently stiff to bring about failure in the gusset and center member. Hence the curve begins to increase less rapidly tending to vary with bolt diameter or bearing area.

Three-quarter-inch plywood gussets gave similar results but at higher loads for bolts ½-in diameter and over.

Length to Diameter Ratio

Hansen (2) points out that the strength of a bolted joint depends partly on the slenderness ratio of the bolt. The effective length of the bolt is assumed in this study to be the thickness of the center member plus one-half the thickness of each gusset. Comparing the proportional-limit average stress of the plywood with length-to-diameter (L/D) ratios indicates that average bolt bearing stresses for ½ and ¾-in plywood gussets follow two separate but similiar relationships. Maximum proportional limit stress occurs in both cases for L/D values between 3 and 5. Referring to Fig. 6, note that the proportional limit stress decreases either way from L/D ratios between 3 to 5. The results shown in Fig. 6 are reduced by a safety factor of 2 from experimental values.

For design purposes the average bolt bearing stress can be divided into three regions of straight-line variations. Working stresses can also be approximated with a sinusoidal relationship. Using a straight-line variation, safe working stresses are given by the following for plywood gussets: For ½-in gussets—

$$0<L/D<3 \quad s_w=1000+\tfrac{2}{3}\ (1000\ L/D) \quad . \quad . \quad [1]$$

$$3\leq L/D\leq 5 \quad s_w=3000 \text{ psi}$$

$$5<L/D<12 \quad s_w=3000-460\ (L/D-5) \quad . \quad . \quad . \quad [2]$$

For ¾-in gussets—

$$0<L/D<3 \quad s_w=1000+1.45/3\ (1000\ L/D) \quad . \quad [3]$$

$$3\leq L/D\leq 5 \quad s_w=2450 \text{ psi}$$

$$5<L/D<12 \quad s_w=2450-350\ (L/D-5) \quad . \quad . \quad . \quad [4]$$

The sine relationship has a period of $\pi L/9D$ radians for both ½ and ¾-in gussets. The basic stress is 1000 psi and the total thickness, t, in inches of the plywood gussets can be expressed in a safe working stress†

$$s_w=1000+2000/t \sin \pi L/9D \quad . \quad . \quad . \quad . \quad . \quad . \quad [5]$$

The sine relationship gives a slight overstress in the region for L/D from 5 to 9, the safety factor actually being reduced from 2 to a minimum of 1.75.

It should be noted that these equations apply only to 5-ply plywood of good balanced design and loads parallel to the face grain. If some safety factor other than 2 is desired, it is only necessary to change the constant term and/or the coefficient of the sine term. The simplicity and ease of application probably makes the sinusoidal variation the most practical from a designer's viewpoint.

Conclusions

- Hankinson's equation is too conservative for calculating bolt bearing strength at angles to the face grain.
- Plywood with balanced design will have approximately equal strength at any loading angle.
- Joints made from dry structural lumber and used in a continuously dry location could be designed for an

†If the sine relationship is more convenient in degrees, then $s_w=1000+\frac{2000}{t} \sin 20 \frac{L}{D}$.

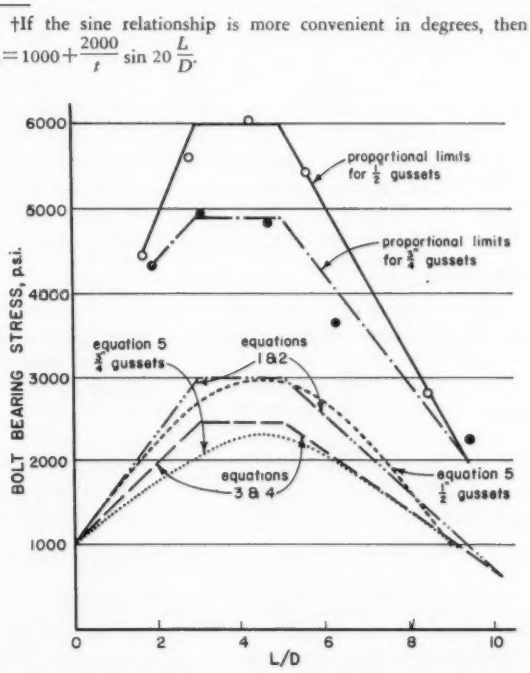


Fig. 6 Variation of proportional limit bolt-bearing stress with bolt L/D ratio and proposed safe-working stresses given by equations [1] to [5]

extra 500 lb per bolt, provided the bolt is fully tightened and the allowable loading on the truss member is not exceeded.

- Tight bolts improve the joint design by distributing the load more uniformly between the joint components.
- Increased bolt diameters would not increase the allowable friction load since compression perpendicular to the grain becomes the limiting factor.
- The most efficient joint design is obtained with length-to-diameter ratios for the bolt between 3 and 5.
- Safe-working bolt-bearing stresses for 5-ply exterior-grade Douglas fir plywood can be expressed as a sinusoidal relationship with bolt L/D ratios.

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ASAE COMMITTEE REPORTS

Sprinkler Irrigation Research Committee

Two tentative standards proposed by the Sprinkler Irrigation Research Committee have been approved by the Council of ASAE for publication in the 1957 edition of the AGRICULTURAL ENGINEERS YEARBOOK. The first is a tentative minimum standard for irrigation equipment; the other a standard for compiling design data for sprinkler irrigation systems.

The standard for irrigation equipment establishes minimum standards for a single category—150-lb class aluminum irrigation tubing. It is anticipated that other categories will be added when standards are formulated to provide reasonable protection and a margin for deterioration in service so as to give a reasonably long, safe period of usefulness. The standard will serve as a reference for minimum requirements by sprinkler irrigation systems. The technical specifications were agreed upon by irrigation equipment manufacturers' representatives at a meeting with the Technical Committee of the Sprinkler Irrigation Association. They were subsequently revised and approved by the ASAE Sprinkler Irrigation Research Committee and the ASAE-SIA Liaison Committee.

The second tentative standard is a data sheet developed by the ASAE Sprinkler Irrigation Research Committee in cooperation with the Sprinkler Irrigation Association, U. S. Farm Home Administration and U. S. Soil Conservation Service. Its purpose is to meet the needs of the field engineer for a data form on which all pertinent information for the design of a sprinkler irrigation system would be recorded and kept as a permanent record. It could be used also as a standardized form for submitting bids for sales of such systems.

Committee on Radiation

A report from John E. Nicholas, chairman of the ASAE Committee on Radiation, lists the proposed objectives and activities of that committee for 1956-57. Need for a radiation committee whose interest in the use of radiation to agriculture is stated to be: (a) to study electrical, electro-magnetic and magnetic phenomena produced by life process—plant and animal—and measure biologically generated radiation of living cells, (b) to study effects of high frequency radiation upon bacteria, enzymes, and disease organisms, (c) to apply knowledge of radiant energy to agricultural problems, (d) to establish the electro-chemical relations of plant nutrients, and (e) to determine the electrical potential of insects and how it is affected by insecticides.

The objective of such committee is to study these problems, encourage research in this field, guide and assist and stimulate the agricultural scientists in all branches.

Chairman Nicholas urges ASAE to assume the leadership in this area by implementing a program, through this committee, to meet the challenge of applying new methods, techniques and knowledge of radiation of all types to agriculture.

Committee on Farm Safety

During the winter meeting of ASAE in Chicago, V. S. Peterson, chairman of the Committee on Farm Safety, pointed out the need for greater participation by all ASAE members in the farm safety program. The committee, called together for a special session, outlined a program of action for the coming year in line with Chairman Peterson's recommendations.

Proposed ASAE standards under study by the committee include the highway lighting problem, electric fence controllers, silo hazards and pressure fertilizer hazards. It was recommended that farm safety be included in every major ASAE program when applicable. This would include the programs of the general session as well as the programs of each major division.

The National Safety Council was commended by the committee for its approach to the corn picker accident survey. It was further agreed that Republic Steel Corp. be formally recognized for supplying subscriptions to Farm Safety Review for all members of ASAE.

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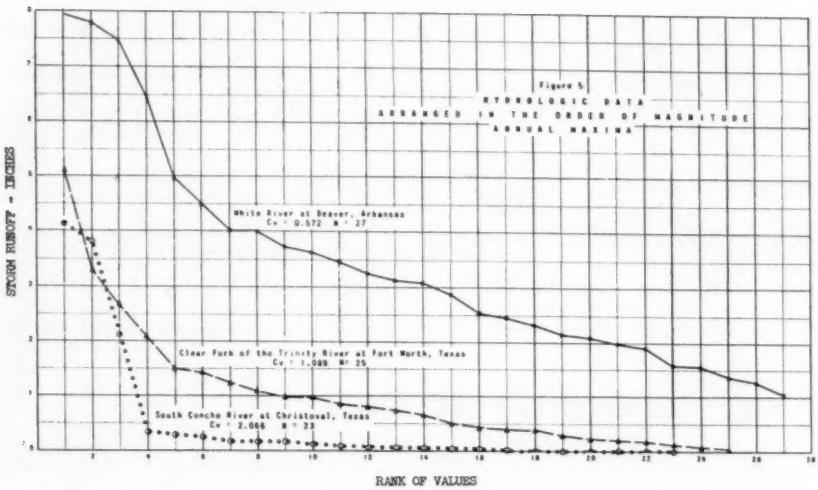
Figure 5
HYDROLOGIC DATA
ARRANGED IN THE ORDER OF MAGNITUDE
ANNUAL MAXIMA
STORM RUNOFF - INCHES
White River at Beaver, Arkansas
Cv = 0.572 N = 27
Clear Fork of the Trinity River at Fort Worth, Texas
Cv = 1.089 N = 25
South Concho River at Christoval, Texas
Cv = 2.066 N = 23
RANK OF VALUES

Fig. 5 Relationship of the order rank of storm-runoff events and the magnitude of the event for two streams in Texas and one in Arkansas

pared with curves from similar streams. Certain types of data from homogeneous regions will tend to group. The tendency can be used to reduce errors and discrepancies in single station records. Fig. 5 shows the relationship of the order rank of storm-runoff events and the magnitude of the event for two streams in Texas and one in Arkansas. These three curves show clearly the regional influence upon the range or dispersion of values as reflected by the coefficient of variation.

It is extremely difficult to define a satisfactory frequency curve, even for the period of record, from data such as that represented by the records from the South Concho River at Christoval. The sample is obviously not homogeneous and frequency analysis is not recommended. It should be noted that for these data the coefficient of variation is about 6 times as great as 0.364, which is the value postulated by the theory of extreme values. The extrapolation of a theoretical or graphical curve fitted to the points would be extremely hazardous.

The data from the Clear Fork of Trinity River represent a sample in which the coefficients of skew and variation are within the range where, by fitting various theoretical curves to the data, satisfactory agreement is obtained in estimating the magnitude of an event that would be expected to occur no more frequently than once in twice the period of records. This is not strictly a homogeneous sample but it may be used with caution. If the theoretical curves and the curves fitted to the plotting points by eye are extrapolated to 100-year frequency the difference in runoff indicated at that frequency is approximately 50 percent. See Fig. 2.

The data from the White River represent a sample in which the coefficients of variation and skew are only slightly above that postulated by the theory of extreme values. Frequency curves determined from the data by the five methods illustrated show only a slight difference in the value of the 100-year frequency event. Extrapolation of any of the curves to 3 or 4 times the period of record could be accomplished with confidence.

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. . . Straight-Sided Splines

(Continued from page 173)

modulus has the least value and $Z=2I/D$. The section modulus is greatest when the load is applied in a plane midway between two splines, and referring to Fig. 2 it is seen that ignoring radii or chamfers on the corners of the splines

$$c=\frac{1}{2}\left\{\frac{W}{\sin\theta}+\left[\sqrt{D^2-W^2}-W\cot\theta\right]\cos\theta\right\}. \quad [7]$$

Polar Moment of Inertia

The formulas commonly used for calculation of torsional deflections and stresses involve the polar moment of inertia. They are applicable only to shafts of round cross section because, according to a principle stated by Saint Venant in 1853, the maximum stress due to torsion of a non-circular section cannot occur at the extreme fiber. Consideration of the membrane analogy discussed by Lee (4) indicates that the maximum torsional stress is more likely to occur at the root of the spline. McCain (5) stated: "Torsional tests of plain splined shafts have indicated that their strength is equivalent to a plain shaft of a slightly less than the minor diameter." Consequently, although the polar moment of inertia is double the moment of inertia in bending, at the present it has no practical significance for splined members. Apparently the best assumption for the calculation of torsional stresses and deflections is to consider a splined shaft to have a circular cross section equal to the root diameter.

Spline Shaft Proportions and Properties

An SAE Standard (1) adopted proportions for soft-broached holes in fittings with 4, 6, 10, and 16 splines. There are three classes of fit: permanent fit, to slide when not under load, and to slide under load. For a given number of splines, only the ratio of root diameter to outside diameter changes with the class of fit; the spline width remains a constant fraction of the outside diameter.

Generally, mating splines are designed to provide a fit on either the root or outside diameter with clearance provided on the diameter where a fit is not desired. Ordinarily only a small clearance, on the order of 0.002 in, is left between the sides of the male and female splines. Consequently, the standard proportions generally do not apply to a spline shaft except that the spline width will approach closely the standard width. Fig. 3 presents graphically the area of 4, 6, 10, and 16 spline sections for the standard spline widths of $0.241D$, $0.250D$, $0.156D$, and $0.098D$, respectively. Likewise, Fig. 4 presents values of moments of inertia. In Figs. 3 and 4 the differences between values for 10 and 16 splines are so small that separate curves cannot be shown.

Because the standard spline width is based on the female part, the values given in the curves are not the precise values for a mating part. However, the error is small, as can be seen from an example of the 1⅜-in diameter 6-spline shaft which is standard for power take-off drives. The minimum outside diameter is 1.371 in, the minimum root diameter is 1.098 in, and the minimum spline width is 0.338 in. Thus, d/D is 0.8009 and W is $0.2465D$. Assuming W is $0.250D$ as in the curve in Fig. 4, I is $0.0356D^4$. The value of I computed from equations 4, 5, and 6 using $W=0.2465D$ is $0.0354D^4$. This is an error of only 0.5 percent as compared to an error of 8.8 percent if the section is assumed to be equivalent to a solid shaft of 1.2345-in diameter, the mean between the root and outside diameters. The presence of a small radius at the root of the splines and a radius or chamfer on the outer corners will have a negligible effect on the values of the cross-sectional area and moment of inertia.

The distance from the neutral axis to the extreme fiber for the greatest section modulus with each number of splines is given in Table 1:

TABLE 1. DISTANCE FROM NEUTRAL AXIS TO EXTREME FIBER FOR GREATEST SECTION MODULUS

No. of splines	Spline width	Distance to extreme fiber
4	$0.241D$	$0.4283D$
6	$0.250D$	$0.4818D$
10	$0.156D$	$0.4938D$
16	$0.098D$	$0.4976D$

The values are for splines without a radius or chamfer on the outer corners and are applicable only if the spline root radius does not exceed the tabulated value.

Summary

Exact equations have been presented for the determination of cross-sectional area, moment of inertia, and section modulus of machine members with straight-sided splines, assuming sharp corners at the root and outside diameters of the splines. The curves present solutions of the equations for splines of standard widths. The curves and data are sufficient for accurate calculation of shear stress, bending stress and beam deflection of shaft and fittings with 4, 6, 10, or 16 splines of standard widths.

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MEMBERSHIP STATUS

"50 Hundred Members in Our 50th Year"

This slogan was originated by ASAE President Roy Bainer during the 49th Annual Meeting in June.

January 1, 1957	4637
January 31, 1957	4681
February 28, 1957	4737
Applications being processed	229

Usually complete processing requires about two months after application has been received by ASAE Headquarters

. . . Pneumatic Conveying of Grain

(Continued from page 171)

test section in a vertical position. Four-inch aluminum irrigation pipe was used throughout the system.

The particles were introduced into the airstream through a bucket-wheel feeder. This was necessary since the static pressure within the pipe reached as high as 12 in of water which ruled out the use of an injector or constricted-area-type feed.

Following is an explanation of the procedure used to determine the various pressure differentials:

Six static-pressure taps were located at four-foot intervals along the test section. The first tap was located 10 ft from the 180-deg bend. This was necessary to allow the particles to reaccelerate to their terminal velocity before the pressure differentials were recorded. The six equally spaced taps were necessary to insure against false pressure differential readings which might include acceleration losses. If steady-state conditions prevailed, each of the four stations would register equal pressure differentials. However, if the particles were still undergoing acceleration, the pressure differential recorded at each station would become successively smaller as the particle acceleration diminished, until constant readings were recorded when the particle acceleration was zero.

Soft white winter wheat was chosen as the material for testing the validity of equations [5], [6], and [7]. Several pressure differentials were recorded for different air velocities and flow rates at each of four pipe inclinations. A thin plate orifice installed before the grain inlet was used to measure the air velocity in the system. Five circular calibrated plates were used to obtain the desired flow rates. Discussion of the results of these test runs follows.

Test Results

The method used to determine the experimental solids' friction factor, f_s, is explained in the following paragraphs.

The experimental pressure drops for a pipe angle of 0 deg were plotted against air velocity as shown in Fig. 4. Next a line of best fit was drawn through each group of points representing one of the five flow rates. (These are *not* the dotted line shown in the figure.) From each of the five experimentally determined curves, it was possible to calculate a curve (graph not shown) of air velocity versus particle velocity. This curve was compatible with the experimentally determined points for that one flow rate. Theoretically, the five pressure - drop - versus - velocity curves should transpose into one identical curve on the graph of air velocity versus particle velocity. The method of calculating the latter curve from the former is as follows: Equation [6] was solved for f_s and set equal to equation [5], thus eliminating f_s as a parameter. For any given air velocity and flow rate, the only variables left in the resulting equation were v_s and C. Now $0.4+40/79.9$ (v_a-v_s) could be substituted for C, thus leaving a simple quadratic equation in one unknown, v_s. After such a curve was drawn for each flow rate, an average curve was fitted and used to calculate the f_s curve shown in Fig. 3. Fig. 3 was in turn used to calculate the theoretical curves shown in Figs. 4, 5, 6, and 7. The degree of accuracy with which the theoretical curves, shown in Figs. 5, 6, and 7, match the experimentally determined points is a measure of the validity of the theory developed. Fig. 4 can not be used as a basis of comparison since it was used to establish f_s.

From Figs. 4, 5, 6, and 7 it can be seen that for a given air velocity the pressure drop increases as the pipe angle increases. This is in agreement with equation [6]. At a pipe angle of 0 deg, the pressure loss and air velocity possess a linear relationship, which is compatible with the theory developed. As the pipe angle increases, the pressure loss increases at a faster rate for low air velocities than it does for high air velocities. This phenomenon is due to the decrease in particle velocity as the pipe angle increases, air velocity and flow rate remaining constant. Since this will cause an increase in the density of the dispersed solids, ρ_{ds}, there will be an accompanying increase in the static-head loss. This same argument can be advanced to explain the change in slope from positive in Fig. 4 to negative in Fig. 5.

If the curves in Figs. 5, 6, and 7 were extended to include an air velocity of infinity, they would again become linear and possess the slope of their equivalent curve in Fig. 4. The following explanation is advanced for this: As the air velocity increases to infinity, the ρ_{ds} decreases to zero; thus the entire solids' pressure drop is due to the sliding component as it is in Fig. 4.

Conclusions

- The experimental data obtained to date indicates that the theoretical analysis is valid. However, at least one more pipe diameter should be tested before experimental friction factors are determined for other grains.
- Pressure drop due to the solids increased as pipe inclination increased.
- Pressure drop due to the solids increased as the air velocity decreased and the pipe angle increased.
- Pressure drop due to the solids increased as flow rate increased for any given air velocity and pipe inclination.
- A linear relationship existed between the pressure drop due to the solids and the flow rate, for any given velocity. (This is not graphically illustrated in this paper.)
- The static head component of pressure drop decreased as air velocity increased.
- The sliding component of pressure drop increased linearly as air velocity increased.

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Following are brief reviews of papers presented at ASAE meetings or other agricultural engineering papers of which complete copies are available. Information concerning copies of these papers may be obtained by writing to the American Society of Agricultural Engineers, St. Joseph, Mich.

Methods of Estimating Evapotranspiration, by G. Levine, assistant professor of agricultural engineering, Cornell University, Ithaca, N. Y. Presented at the winter meeting of ASAE in Chicago, Ill., December, 1956, on a program arranged by the Soil and Water Division. Paper No. **57-13.**

This paper served as the introductory paper to the symposium on evapotranspiration. It reviews briefly some of the methods that are available for evaluating evapotranspiration from observable meteorologic data.

These methods can be grouped into three categories: empirical methods in which arbitrary factors are fitted to existing data, theoretical methods based upon the theory of vapor diffusion, and theoretical methods based upon the balance of energies available and used in the evaporation process. The Blaney-Criddle and Thornthwaite methods are representative examples of the first category. The Thornthwaite-Holzman equation is representative of the second group, and the Penman method is an example of the energy-balance theory.

Each of these methods is discussed in the paper and includes, in addition to the basic assumptions, comments upon the advantages and limitations inherent in each method. An example of the calculations involved in these three methods is presented, using data representative of areas in which the methods have been used.

Heating Farm Homes with Electricity—Resistance, by Sterling S. Sanford, supervisor of steam sales, Detroit Edison Co. Presented at the winter meeting of ASAE in Chicago, Ill., December, 1956, on a program arranged by the Rural Electric Division. Paper No. **57-17.**

The two general types of resistance heating systems are where the heaters are located in the rooms to be heated, and where the heater is located at a central point and heat is distributed by pipes or ducts. The first type is the more common and is the one discussed in this paper. Electric heating equipment is divided into three classes: ceiling heating, wall heaters, and baseboard heaters.

The paper explains that it is good practice to insulate an electrically heated house with 4 to 6 in of insulation in ceilings, 3⅜ in in walls and 3 in under floors. The heat loss of a house can be calculated by conventional methods and expressed in Btus per hour or watts. Thirty-five electrically heated homes in southeastern Michigan were studied by use of meters on the heating load, and averages cited. The kilowatthours consumed were the same as would be obtained from the FHA and NEMA formulas for space heating if constants of 14.1 and 24.1, respectively were used.

The amount of heat used was less than usually supplied by fuel-fired equipment because no outdoor air is needed for combustion thus reducing loss by air changes, room control eliminates overheating, the temperature is reduced in unused rooms, people are more careful with the use of electric heat than with fuel because of cost, and there are no losses from a central unit. Some of the advantages claimed for electric heat are cleanliness, safety, comfort, convenience, reliability, quietness, appearance, space saving, low maintenance and low first cost.

Equipment For Placement of Fertilizer and Seeding in Permanent Sod, by T. N. Jones, agricultural engineer, Mississippi Agricultural Experiment Station, Mississippi State College. Presented at the winter meeting of ASAE in Chicago, Ill., December, 1956, on a program arranged by the Power and Machinery Division and the National Joint Committee on Fertilizer Application. Paper No. **57-15.**

The practice of sod seeding has introduced a new principle for seeding grazing crops in established sod, such as small grains, grasses and legumes during the period when the sod is dormant, or near dormant. It can also be used to plant summer crops in grain stubble. This paper points out that this principle does not destroy the sod, but, if seeded on the contour, prevents major soil and water loss and reduces the cost of seeding grazing crops.

Recent developments in farm equipment have made this practice practicable. Equipment has been designed or adapted to open a narrow furrow in existing sod, deep place fertilizer, with seed above but not in contact with fertilizer, that results in minimum disturbance of the sod. In order to serve the farm areas, several machines have been developed, including two-row tandem machines with combinations of fertilizer applicators.

Trends In The Use Of Liquid Fertilizer, by H. H. Tucker, agricultural service director, Sohio Chemical Co., Lima, Ohio. Presented at the winter meeting of ASAE in Chicago, Ill., December, 1956, on a program arranged by the Power and Machinery Division and the National Joint Committee on Fertilizer Application. Paper No. **57-19.**

This paper discusses the use of liquid fertilizers, anhydrous ammonia and nitrogen solutions as an additional method of supplying needed plant nutrients to growing crops. The advantages include the ease of transfer and handling, speed of application and ready availability to growing plants. The methods of applying different types of liquid fertilizer are explained and the factors that determine the extent of use of this method of fertilization are discussed.

Heat Transfer in Cooling Fruits and Vegetables, by Rene Guillou, agricultural engineer, University of California, Davis. Presented at the winter meeting of ASAE in Chicago, Ill., December, 1956, on a program arranged by the Committe on Agricultural Processing. Paper No. **57-16.**

Effectiveness of a cooling operation is measured conveniently by the time in which the temperature difference between the product and the heat sink is reduced by one-half. This paper develops the mathematical relations of such a half-cooling time to intermediate times and temperatures, pointing out the ease with which this constant is determined and that it gives by inspection the times in which the initial temperature difference will be reduced by ¾, ⅞, etc.

Refrigeration supplied mechanically or by ice usually constitutes one-half or more of the total cost of cooling. Losses from conduction and infiltration into cooled spaces and from the energy introduced by large fans may exceed the heat given up by the product and should be estimated in a new design. Exposing containers to moderate air velocity in a cold room or refrigerator car is the simplest cooling method. The paper points out that time is saved by blasting air into open containers or by placing containers in high-velocity air in a tunnel, but fan and refrigeration costs are increased. Forcing air through containers by static pressure is under investigation and may be equal in speed to other methods of air-cooling and more economical of fan power.

The complete paper discusses hydro-cooling and vacuum cooling and appends a table of half-cooling times.

Some Notes on Drainage Structures, by M. M. Culp, head, design section, (SCS), USDA, Washington, D. C. Presented at the winter meeting of ASAE in Chicago, Ill., December, 1956, on a program arranged by the Soil and Water Division. Paper No. **57-18.**

Drainage structures may be classified on a functional basis as removal structures, protection structures, accommodating structures, and sustaining structures. Removal structures remove and convey the excess water from the area being drained. Protection structures protect the area from external water. Accommodating structures are those that are necessary to accommodate the drainage works to the other works and necessities of man. The sustaining structures are those which support or prolong the usefulness of the previous classes.

The paper points out that structural durability depends upon sound design and construction, but, because many drainage structures are small, too little attention is given to this. A description of the Island Type Dam as to the way it works and the economy of its design is included. This type structure is desirable for controlling head erosion at the upper end of many open ditches and to provide stable outlet for tile lines from upstream areas.

Field Evaluation of Evapotranspiration, by William A. Raney, soil scientist, ARS, USDA, Beltsville, Md. Presented at the winter meeting of ASAE in Chicago, Ill., December, 1956, on a program arranged by the Soil and Water Division. Paper No. **57-20.**

This paper reports that in the eastern one-half of the United States evapotranspiration can be measured in 40 x 40-ft irrigation plots with relatively high precision and accuracy. In such cases, soil moisture measurements, which are used as indices of moisture accretion and depletion, may serve as a basis for calculation of evapotranspiration. In addition to measurement of moisture content, the movement of moisture, both laterally and vertically out of the root zone, must be measured. Evapotranspiration is the difference between total moisture depletion from the plots and the amount of moisture that moves laterally and vertically beyond the root depth.

Third International Irrigation Congress

The Third International Irrigation Congress will meet April 29 to May 18 in California. Registration, inaugural, and technical sessions from April 29 to May 4 will be held at the Sheraton-Palace Hotel in San Francisco. The closing session on May 18 will be held at Los Angeles.

Study tours have been arranged for May 6-17. Visits will be made to irrigation and drainage works, to irrigated farms, and to places of general interest. Local visits will be arranged both in San Francisco and in Los Angeles, and there will be a separate program for the ladies.

The technical sessions will be devoted to discussion of questions on canal lining, soil water relationship in irrigation, hydraulic structures on irrigation and drainage systems, and the interrelation between irrigation and drainage. The committee expects a record attendance because of the growing concern with water problems.

The Irrigation and Drainage Division of the American Society of Civil Engineers will hold a conference on April 29-30, and a joint meeting with the Pacific Coast Section of the American Society of Agricultural Engineers and the Soil Scientists Association of America on April 30. Delegates to the Third Congress are invited to the conference and the joint meeting.

Elected to Life Membership

The Council of ASAE during its winter meeting sessions at Chicago in accord with the provisions of Society By-Laws conferred upon the following members the grade of Life Member: C. J. Allen, L. R. Clausen, A. W. Clyde, C. M. Eason, F. C. Fenton, L. F. Livingston, R. P. Messenger, Virgil Overholt, B. B. Robb, G. L. Shanks, C. W. Smith, H. B. Walker and W. W. Weir.

So. Dakota AE Building Burned

The agricultural engineering building at South Dakota State College was destroyed by fire January 22. Only five pieces of agricultural machinery, some desks, book cases and about 75 percent of research records were saved. In addition to being the home of agricultural engineers, the building furnished rooms for several agriculture and mathematics classes. The loss was not covered by insurance.

The teaching program is continuing under temporary housing and rearranged class schedules.

EJC Income Report

The Engineers Joint Council 1956 report of professional income of engineers is now available for general distribution. It is priced at $1.50 per copy.

This report is based on engineering income figures for 1956 on about 110,000 engineering graduates employed in industry, government and engineering education. Data is presented in various graphic and tabular forms.

Student Transfer Contest

Several of the ASAE Student Branches have entered a "Membership Transfer" contest. Competing Branches have supplied ASAE headquarters with a list of names of graduating seniors. At the end of the year, the number of these seniors who apply for admission into the Society will be reported and the percentage that transfer will constitute the score for the Branch.

In addition to getting the graduates off to an early start in the affairs of their profession, the contest will actually help them to save the expense of the Society's admission fee. ASAE By-Laws permit a graduate in agricultural engineering to transfer from student to corporate membership without paying the admission fee, provided his application is received at ASAE headquarters by December 31 of the year of graduation. By submitting his application as required for the Membership Transfer Contest, the student will meet this requirement and save the admission fee.

The first Branch to submit an entry list was the Idaho Student Branch. They were followed closely by Texas, Missouri, Alabama, and Oregon. Several others have indicated that their lists would be mailed in the near future.

Irrigation Conference

The Pennsylvania Sprinkler Irrigation Conference will be held in the Extension Conference Center at the Pennsylvania State University Campus on March 28-29. The discussions will be of interest to agricultural county agents, irrigation equipment manufacturers, distributors, dealers and salesmen, soil conservation technicians, electric power suppliers and others who are in a position to advise farmers concerning the design, purchase and operation of irrigation systems. Several ASAE members are included on the program.

ASAE Meetings Calendar

March 28 and 29 — SOUTHWEST SECTION, Memorial Student Center, A & M College of Texas, College Station, Texas

March 29-30 — MID-CENTRAL SECTION, Hotel Robidoux, St. Joseph, Mo.

April 5-6 — ROCKY MOUNTAIN SECTION, University of Wyoming, Laramie

April 11-12 — ALABAMA SECTION, Battle House Hotel, Mobile, Ala.

April 11-12 — PENNSYLVANIA SECTION, Pennsylvania State University, University Park

April 24 — MICHIGAN SECTION, Howell Boy Scout Camp, Brighton, Mich.

April 26 — QUAD CITY SECTION, place not announced.

April 26-27 — FLORIDA SECTION, Lakeland, Fla.

April 27 — OHIO SECTION, Ohio State University, Columbus

June 23-26 — GOLDEN ANNIVERSARY ANNUAL MEETING, Michigan State University, East Lansing

August 27, 28 and 29 — NORTH ATLANTIC SECTION, University of Delaware, Newark

December 15-18—WINTER MEETING, Edgewater Beach Hotel, Chicago, Ill.

NOTE: Information on the above meetings, including copies of programs, etc., will be sent on request to ASAE, St. Joseph, Mich.

Gas Turbine Conference

The 1957 meeting of the National Conference of the Gas Turbine Power Div. of the American Society of Mechanical Engineers, will be held March 18-21 at the Sheraton Cadillac Hotel. The three-day program will deal with a number of aspects of gas turbines including automotive use.

Representatives of European automobile manufacturers will describe progress in their countries on developing gas turbines for automobiles. Engineers from Ford Motor Co., General Motors Corp., and Chrysler Corp. will also take part in the program. Additional papers will deal with such topics as use of gas turbines for aircraft, ship propulsion, industrial power generation and chemical and nuclear plants. Supplementing the technical sessions will be an exhibit area in which manufacturers will display new developments in gas turbines and related items.

Annual Meeting Extension Exhibits

A call for outstanding exhibits for the ASAE Golden Anniversary Meeting at Michigan State University in June, 1957, has been sent out by the ASAE Extension Committee. Anyone interested in submitting entries should contact the committee chairman, J. C. Oglesbee, Jr., 1020 Crescent Ave., N.E., Atlanta 9, Ga.

Exhibits may be entered in any or all of the following classifications: demonstration models, movies, slides and film strips, publications (periodicals and bulletins), new textbooks, radio and television, and extension method outlines. Blue ribbon awards will be made for exhibits judged best in each class.

There will be two classifications of demonstration models—industrial or commercial and public agency. The committee is encouraging the use of small portable models which can be assembled into larger exhibits.

Awards in motion pictures will be offered for those prepared by industrial or commercial organizations, and those prepared by colleges, universities and other public service groups. Slides or film strips which have agricultural engineering implications can be entered under either public agency or industrial classification. Publications which include both bulletins and periodicals can also be submitted under these two classes. One person is limited to one bulletin entry and/or one periodical entry. The periodical entry includes news letters and other educational publications issued at intervals.

No awards are made for new textbooks, but a display will give agricultural engineers an opportunity to examine textbooks that are available for reference material or teaching. Television is becoming a popular teaching tool and charts, photographs, models and other materials that can be used on TV programs are welcome. Any special technique for handling radio programs that can be exhibited may be submitted.

Extension methods exhibits are limited to extension agricultural engineers. Recipe or method outline forms for conducting a successful activity in agricultural engineering extension will be reproduced and sent to all extension agricultural engineers who have interest in this material. These forms serve this group by giving them ideas on how programs can be improved.

HEADQUARTERS FOR GOLDEN ANNIVERSARY MEETING

Headquarters for the ASAE Golden Anniversary Meeting will be in Shaw Dormitory, one of the world's largest student dormitories. Here, also, most of the visitors will be housed. Special "package" rates for housing and meals makes Shaw Dormitory attractive for visitors. One person can have lodging and meals from Sunday evening, June 23, until Wednesday noon, June 26, for approximately $20.00. The Wednesday evening banquet will be extra

Golden Anniversary Meeting

The Golden Anniversary Meeting of the American Society of Agricultural Engineers will be held at the Michigan State University campus in East Lansing on June 23-26. ASAE members and friends from the United States and foreign countries, including many of the leaders of industry, education and government will attend.

The theme for the meeting is "Looking to the Future". A program is being planned which will bring top men of industry, government and education, including foreign experts, to report on present and past developments in the field and to emphasize looking to the future. All divisions of the Society are planning a technical program where an opportunity will be given to see and hear world famous speakers who are interested in helping to develop the agricultural engineering profession.

On Sunday night, June 23, the Hospitality Supper will open a get-acquainted program and on Monday night after an ox-roast, there will be a square dance. The FEI student dinner will be held on Tuesday night. All ASAE student members are urged to attend the 50th annual meeting. Wednesday night will be the annual banquet, where awards will be presented, and recognition given to leaders of industry and of members in the profession. This will be followed by a dramatic presentation portraying the 50 years of development in agricultural engineering. It will be an "Our Town" type of production with a narrator, lights and sound effects. The need for engineering in agriculture, a gathering of the small group of founders, deliberations and philosophies, the struggle to be accepted and recognized, the effect of wars on the development of engineering in agriculture, accreditation and acceptance of the profession, and new horizons in the future will be chapters in this fast-moving tableau.

It is planned to invite a nationally famous leader of industry to give the banquet address carrying out the theme of looking to the future.

On Thursday, June 27, a special seminar on graduate work and another on extension will be held. The special public works and public lands program will continue through Thursday. Thursday and Friday will be set aside for major sight seeing tours to the Detroit area. There will be daily local tours to points of interest on the campus and in the Lansing vicinity. The campus tour will show a complete food handling system to accommodate an equivalent town of 20,000, and other scheduled tours will include automobile factories, an elaborate television station, a bakery, and a potato chip plant.

The extension exhibit is planned to be expanded this year and will be of interest to all in attendance. Other exhibits will be designed to show equipment that is in the research and development stage, and equipment that is not commercially available, but expected to be in the next few years. These exhibits will be located in the agricultural engineering building and will consist of a solar battery, a solar powered pump, solar grain drying equipment, a solar furnace and a solar mobile. A model of an atomic power plant, an air conditioned tractor, historical exhibits of farm machinery development, fuel injection systems for farm power units and gas turbine engines and exhibits to show foreign farm machinery developments are being planned. A modern industrial design exhibit of materials for building light triangular shaped frame structures, a U.S. weather bureau display on the formation and spotting of tornadoes and a display of historical drain tile will be of interest to all.

Programs are being arranged for the ladies and children who attend the Golden Anniversary meeting. There will be a luncheon for wives and a bridge party for the ladies who enjoy bridge. Also a series of topics of primary interest to the ladies are to be presented in special meetings each morning.

Programs have been arranged for children of all age groups, as well as special entertainment for all children during the evening of the banquet. Arrangements are being made to have baby sitters available at all times and there will be a nursery school for children in the 2½ to 5 year age group. Recreation, such as swimming, ice skating, a bus trip and a picnic lunch at the zoo, is planned. One evening during the meeting will be set aside for a supper and square dance for the teen-agers.

Headquarters for the Golden Anniversary meeting will be in Shaw Dormitory where most of the visitors will be housed. It is located on the banks of Red Cedar River and special "package" rates for housing and meals will be available to give low cost accommodations.

Lodging and meals from Sunday evening until Wednesday noon will be available for approximately $20.00.

Charles J. Scranton, for the past 22 years chief engineer at Allis-Chalmers Mfg. Co., La Porte, Ind., has been appointed general development engineer. He will devote his time to product development.

Paul H. Harrer, assistant chief engineer for the company's harvesting equipment at La Porte since 1948, succeeds Mr. Scranton as chief engineer. He started with Allis-Chalmers in 1938 after graduation from Montana State College with a B.S. degree in mechanical engineering.

Mr. Scranton was born at Peoria, Ill. He graduated from Bradley Polytechnic Institute, now Bradley University, at Peoria, in 1912. In 1934 he became chief engineer at Allis-Chalmers Mfg. Co., and has been responsible for the design and development of a line of grain, corn, hay, and silage tools which have been distinctive in design and performance. He has been active on the Farm Equipment Institute's advisory engineering committee, in the Society of Automotive Engineers, and the American Society of Agricultural Engineers. In 1952 he was awarded the Cyrus Hall McCormick Gold Medal by ASAE.

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Hal E. Bland has been appointed to the position of sales manager, produce equipment, for the Aeroglide Corp. in Raleigh, N. C. He will be directly responsible for the field research, promotion and sale of vegetable and fruit handling equipment. He was formerly employed by the Tractor and Implement Division, Ford Motor Co., in the Product Planning Dept.

After graduation from Clemson College with a B.S. degree in agricultural engineering, he worked as project leader of the cotton mechanization work at the Clemson College Experiment Station in Clemson, S. C. Later he joined Engine Parts Mfg. Co., Cleveland, Ohio, as their Southern representative and worked directly with colleges, USDA, farm equipment dealers and farmers.

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Mason Vaugh will retire in April from his position as professor of agricultural engineering at the Allahabad Agricultural Institute in India, where he has been since 1921. He plans to return to the United States in June, 1957, and will be on furlough until June, 1958.

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R. C. Conner has been appointed as general manager, and **A. M. Lane** as general sales manager of a new mobile hydraulics division, Vickers, Inc., Detroit, Mich. This new division will take complete responsibility for all hydraulic equipment used on automobiles, trucks, construction equipment, materials handling, farm machinery and other ground mobile applications.

Mr. Conner has been with the company since 1948 in various engineering and sales capacities, most recently as manager of the automotive division. Mr. Lane joined the organization in 1940 as an application engineer; he has managed several branch offices and the mobile sales department.

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C. J. SCRANTON

P. H. HARRER

H. E. BLAND

Edwin L. Miller, formerly assistant service manager with Harry Ferguson, Inc., Detroit, Mich., has accepted a position as field engineer for the Standard Oil Co. in Columbus, Ohio.

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C. George Krieger has been appointed special assistant to the director of public relations for Ethyl Corp. Mr. Krieger has been associated with the company since 1929 and will be in charge of public relations in the agricultural field. He has served as chairman of the Fuels and Lubricants Committee of ASAE.

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Albert E. Powell has been named agricultural engineer for Douglas Fir Plywood Association, Tacoma, Wash. His headquarters will be in Ames, Iowa. Formerly he was regional manager for the company's field promotion offices in Kansas City, Mo. He has been with Douglas Fir Plywood Association for seven years.

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Thomas V. Wilson has accepted a position as professor in agricultural engineering and agricultural engineer at Clemson College. He will be engaged in teaching and research in the soil and water field. He formerly held a similar position at North Carolina State College.

R. C. CONNER

A. M. LANE

Robert S. Palmer, former chairman of the agricultural engineering dept. at the University of New Hampshire, has resigned to become research project leader in the Eastern Soil and Water Management Section, (SWCRB, ARS) USDA. He will be headquartered at Durham, New Hampshire.

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John J. Kolega, has resigned from the agricultural engineering staff at the University of Connecticut to accept an appointment as chairman of agricultural engineering department at the University of New Hampshire. He will fill the vacancy left by the resignation of Robert Palmer.

(Continued on page 204)

NECROLOGY

Irvin H. Althouse, ASAE Fellow, died January 8 in Porterville, Calif. He was born on December 10, 1887 in Fremont, Nebr. He had two years of education in technical high schools in San Francisco and the balance of his training was found in the school of "hard knocks and experience." He began the practice of civil engineering in 1908 upon his arrival in Porterville, Calif.

He was recognized as one of the outstanding hydraulic engineers in the Tulare County area and contributed to water development in the San Joaquin Valley. During recent years he served as secretary of the Friant Water Users Association and was a member of the executive committee of the Irrigation Districts Association for a number of years. He was active in the underground water problems of the State of California and served as chairman of the Underground Water Committee of the California Irrigation Districts Association.

Mr. Althouse was a member of the American Military Engineers, the National Reclamation Association, the American Geophysical Union, and the American Society of Civil Engineers in which he was awarded a life membership in 1954. He joined ASAE in 1926 and served as vice-chairman of the Pacific Coast Section in 1935. He was a registered civil engineer in the State of California.

Fred Strauss is associated in the engineering activities Mr. Althouse carried on and will continue with the work. A Concurrent Resolution No. 24 was passed by the Senate of the State of California honoring Mr. Althouse.

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Frank J. Drayton, agricultural engineer, product planning, Tractor & Implement Division of Ford Motor Company, died recently of a heart attack.

He was born in Toronto, Ontario, Canada, on February 2, 1907. He attended McTavish Business College in Edmonton, Alberta, and the University of Detroit. After merchandising experience with Sears Roebuck and J. L. Hudson, he entered the farm equipment business as a buyer with Harry Ferguson, Inc., in 1942. In 1947 he became associated with Dearborn Motors Corp., continuing with the Tractor and Implement Division of Ford Motor Co. until the time of his death.

Mr. Drayton was active in scouting and church work. He is survived by his wife and three children.

Reports from Local Sections

Items used in this column must be received by the 20th of the month preceding publication date

Chicago Section

The Chicago Section will hold a dinner meeting March 11 at the Toffenetti Restaurant, 57 W. Randolph, Chicago.

Everett Mitchell, NBC radio farm expert, will show colored slides and tell of a 5000-mile tour of farms in Russia which he conducted for 25 U.S. farmers. They visited an agricultural exhibit in Moscow and also observed agricultural areas in Sweden, Denmark and Ireland.

Southwest Section

The Southwest Section meeting will be held at the Memorial Student Center of the Texas A & M College in College Station, Texas, on March 28-29.

The program for Thursday morning, March 28, will be devoted to presentation of papers on electric house heating with heat pump by M. J. Lewis; durability of floor coverings and bathroom walls by B. R. Stewart; and landscape illumination—its significance and potential by John Watson. J. L. Butt, ASAE secretary, will speak on the Golden Anniversary of ASAE. Xzin McNeal, Section chairman, will preside.

A student program will also be held Thursday morning with Harold Sattler presiding. Following reports of student branch activities, an address on advantages of advanced degrees will be given by Russell Benedict. A business session will close the student program.

Two concurrent programs are scheduled for the afternoon of March 28 on farm structures and soil and water. The farm structures session will be presided over by Vice-Chairman Charles E. Ball and will include papers on new techniques in tilt-up construction by Ivan Winsett; comfort condition in aluminum houses by T. R. C. Rokeby; and equipment for evaporative cooling in agricultural production by R. C. Jaska. A symposium on new developments in grain drying and storage will be presented by F. T. Wratten, Xzin McNeal, D. L. Calderwood and J. S. Cook.

W. T. Burtschi, SCS, USDA, will preside over the soil and water session. F. R. Crow will talk on plastic liners for seepage control in farm ponds; I. L. Saveson and Z. F. Lund on deep tillage for crop production; and W. O. Ree on friction factors for quick-coupled sprinkler pipe. E. D. Butler, L. F. Lawhon, B. B. Bryan, J. E. Garton and E. L. Thaxton will be members of a symposium to discuss new developments in irrigation. A tour of the campus will follow the two programs.

H. G. Le Tourneau will be the speaker for the banquet Thursday evening. Chairman Xzin McNeal will preside.

Friday morning, March 29, will be devoted to discussions on heavy duty electrically driven machinery by C. E. Birdsong; new developments in cotton strippers by E. M. Smith, draft of ammonia applicator feet by H. E. Butler; and hydraulic motors for agricultural equipment by E. L. Asch. W. H. Carter, secretary-treasurer, will preside. A business session will close the section meeting.

Rocky Mountain Section

A meeting of the Rocky Mountain Section will be held April 5-6 in the agricultural building at the University of Wyoming, Laramie. Registration will begin at 8:30 a.m., April 5. President Roy Bainer will be the dinner speaker that evening.

Papers to be presented during the meeting will be on waterspreading — a practice in a watershed development program, by Winfred Glover; the upper Colorado River story, by H. T. Persons; evaporation supression: a progress report, by G. Earl Barbeck, Jr.; agricultural engineers—where to in education, by Walter M. Carleton; the effect of moisture on the physical properties of grain, by Robert Lorenzen; cotton mechanization, by Lambert H. Wilkes; adapting buildings to new trends in agriculture, by Earl D. Anderson; some equipment used for and problems involved in seeding grasses on range land, by staff members of Colorado A & M College and the University of Wyoming; and on drying grain on the farm, by Nolan Mitchell.

Alabama Section

A meeting of the Alabama State Section will be held on April 11-12 at the Battle House in Mobile, Ala. The first day will be devoted to registration, a boat tour of Alabama State Docks, and a tour of the Ideal Cement Co. A banquet will be held in the evening with Martin Johnson as the principal speaker.

Friday morning, after the welcome by Mario Bottesini, president of Mobile Junior Chamber of Commerce, papers will be presented on efficiency in farm management, by Emmett Gaston; egg cleaning, grading, and cooling, by H. L. McFarland; and the use of concrete on the farm, by Mayfield Shilling. Following a short recess Harold Bisbort will discuss development of Alabama's water resources, and J. D. Miller will talk on irrigation and related problems.

A business meeting will close the session.

Michigan Section

An evening dinner meeting will be held for members of the Michigan Section and their wives, in the main lodge at the Boy Scout Camp south of Brighton, Michigan, April 24.

The main after-dinner address will be given by ASAE President Roy Bainer. The new sectional officers for the coming year will be installed and A. W. Farrall will report on the Golden Anniversary meeting.

Entertainment, consisting of special musical numbers, is being planned along with square dancing following the dinner meeting.

Mr. Bainer will be on the Michigan State University campus, April 23. He will speak to the University Men's Club and to the Student ASAE Club. He will also meet with the local arrangements committee to discuss plans for the Golden Anniversary Meeting.

North Atlantic Section

The North Atlantic Section meeting will be held August 27, 28 and 29 at the University of Delaware, Newark, Del. A general session on instrumentation is scheduled for the morning of the third day. An evening meeting on August 29 will be devoted to a discussion on energy. Tours, sightseeing, private conferences, etc., are being planned. The complete program will be reported at a later date.

Pacific Northwest Section

The new officers elected for the coming year at the Pacific Northwest Section meeting in October are: Chairman, F. G. Maloney; 1st vice-chairman, H. E. Wichers; 2nd vice-chairman, D. W. Works; 3rd vice-chairman, E. L. Watson; and secretary-treasurer, S. J. Mech.

Members of the Alabama Section visited the Winfield Substation of the Alabama Agricultural Experiment Station to observe a surface irrigation demonstration during the fall meeting held October 11 and 12

This column contains letters in which our readers have expressed opinions, suggestions, unusual experiences, or divergent views on subjects of an agricultural engineering nature. It is the intention of the editor to publish a few such letters in each issue of AGRICULTURAL ENGINEERING to encourage free expressions and open debate on pertinent and timely topics.

Takes Divergent View on Subirrigation Design

TO THE EDITOR:

The article "Design of Subirrigation Systems" by R. L. Fox, J. T. Phelan, and W. D. Criddle in the February 1956 issue of AGRICULTURAL ENGINEERING contains assumptions and simplifications that in the opinion of the author of this letter are not in harmony with the general theoretical character of the publication. In view of the possibility of application of the equations presented in the article under conditions where these assumptions may not be permitted, a further theoretical discussion was considered appropriate. This contribution to Readers' Forum is essentially a condensed form of correspondence with the authors of the article, which was initiated in March, 1956. The divergent viewpoints appeared to be centered around two problems, which are discussed in the order of appearance in the article. The nomenclature is the same as the nomenclature used in the article in question.

The possibility of the existence of a phreatic surface at some distance below the bottom of the irrigation ditches at steady state.

On page 103 of the article, second column, line 13 from bottom, the statement is made that "Water is run into these feeder ditches, under control, and allowed to seep out and feed the water table." This statement implies the existence of an unsaturated zone with water tensions between the ditch bottom and the phreatic surface (hatched zone in Fig. 1). This is in contrast with the picture often presented in the subirrigation literature, showing the phreatic surface at the ditches to coincide with the water level in the ditches (Fig. 2). The importance of knowing the true position of the phreatic surface near the ditches becomes apparent in the evaluation of the quantity d, which appears in the equations for the recommended ditch spacing W. Should d be measured from the water level in the ditches (Fig. 2) or from some point below the ditch bottoms where presumably "seep" flow would change into saturated flow (Fig. 1)? Several arguments in favor of the conditions of Fig. 2 can be presented:

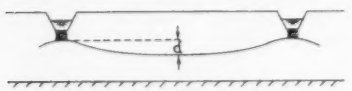


Fig. 1. Flow system with phreatic surface below ditch bottom and unsaturated zone in between.

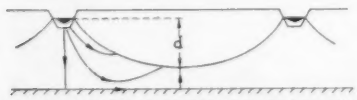


Fig. 2. Continuous gravity-flow system with phreatic surface coinciding with water level in ditches.

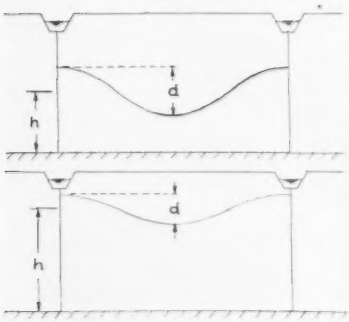


Fig. 3. Flow systems for different combinations of h and d but same product hd.

1. Equation 19 on page 106 of the article in question shows the quantities h and d in product form ($T=Ph$). Consequently, given a certain permeability P and consumptive use u, it is possible to obtain the same ditch spacing W for a whole range of h and d values as long as the product hd is kept constant (Fig. 3). There seems to be no criterion that would determine at which particular h-d combination the steady state will be reached as long as the phreatic surface is below the ditch bottom. As a matter of fact, it would seem quite a coincidence if the steady state were reached at the predetermined design-values of h and d. More acceptable, however, is the thought that the possibility of a whole range of h and d values makes it unlikely that steady state can be reached as long as the phreatic surface is loosely located at some distance below the ditch bottom and not positively tied in with the geometry of the flow system. In that case the integration at the bottom of page 105, second column, cannot be carried out without including a time factor. The only possibility for steady state seems to be the h-d combination whereby the phreatic surface coincides with the water level in the ditches.

2. The condition in Fig. 2 occurs after heavy rainfall that raises the water table above the water level in the ditches (Fig. 4), and subsequent lowering of the water table due to drainage and consumptive use until steady state. This condition can be expected in humid areas where water is let into the ditches to prevent the phreatic surface, built up by winter or spring rains, from dropping below a certain level during the season. There is no reason for the phreatic surface to break loose from the water level in the ditches to assume a new position below the ditch bottom with the formation of an unsaturated zone in between. Therefore, in the design, d should be taken with respect to the water level in the ditches.

3. Sharp drops between the water level in the ditch and the phreatic surface in the soil near the ditch, as sometimes observed with borings, are no indication of an extension of the phreatic surface at some distance below the ditch bottom. The soil permeability near subirrigation ditches sometimes decreases because of translocation of small particles. Since the wetted perimeter of the ditches is usually small compared to the cross-sectional flow area in the field and since the whole flow undiminished by consumptive use and seepage losses is involved, mild permeability decreases tend to result in considerable head losses. In that case, however, it would theoretically seem more correct to apply a reduction factor to the d-value as measured from the water surface in the ditches instead of arriving at a lower d-value by assuming the phreatic surface to be at some distance below the ditches. Uniform, sandy soils will tend to suffer less from sealing effects than well-graded soils.

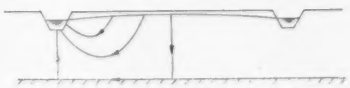


Fig. 4. Phreatic surface above water level in ditches after rains

4. Although tensions and unsaturated zones have been observed under irrigation canals, tensions are difficult to visualize at steady state below bottoms of subirrigation ditches in a regular system. Under those conditions, water fronts from adjacent ditches eventually meet, back-up effects reduce tensions, and finally complete saturation is reached. In terms of the viscous-flow analogue, this process can be explained as follows. Taking two narrowly spaced parallel and vertical plates, a viscous liquid is injected between the plates at two points, representing the ditches. Initially, the liquid moves mainly downward under the forces of gravity and capillarity. The latter also cause a slight lateral flow to a certain extent. The liquid mass is originally oval-shaped and tensions occur due to the capillary forces along the periphery of the liquid. When the impermeable layer (bottom of flume) is reached, the flow is deflected laterally, and the liquid fronts from the two points eventually meet at mid-distance between the two points. At that moment, part of the liquid to air contact is replaced by a liquid to liquid contact, which results in a reduction of capillary action and a corresponding reduction in tensions. This process continues until finally, at steady state, a continuous gravity-flow system is established with tensions occurring only in the capillary zone above the phreatic surface.

The limitations of substitution of the slope of the water table for the actual hydraulic gradients occurring in the flow system.

On page 105 of the article, second column, lines 30 and following, the assumption is made that "the thickness of the water-saturated material is large as compared to the variation in depth between the ground surface and the water table." The authors then proceed by substituting the slope of the water table for the hydraulic gradients along the streamlines (Equation 4). This substitution, or rather this approximation, however, can only be made in case of small h-values. In this respect, the magnitude of h (=thickness of water-saturated material) must be considered in relation to the ditch spacing W. A condition where h is small in relation to W is shown in Fig. 5. The streamlines run more or less parallel and close to the phreatic surface, so that the gradients along the streamlines do not differ

(Continued on page 202)

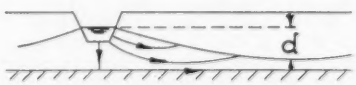
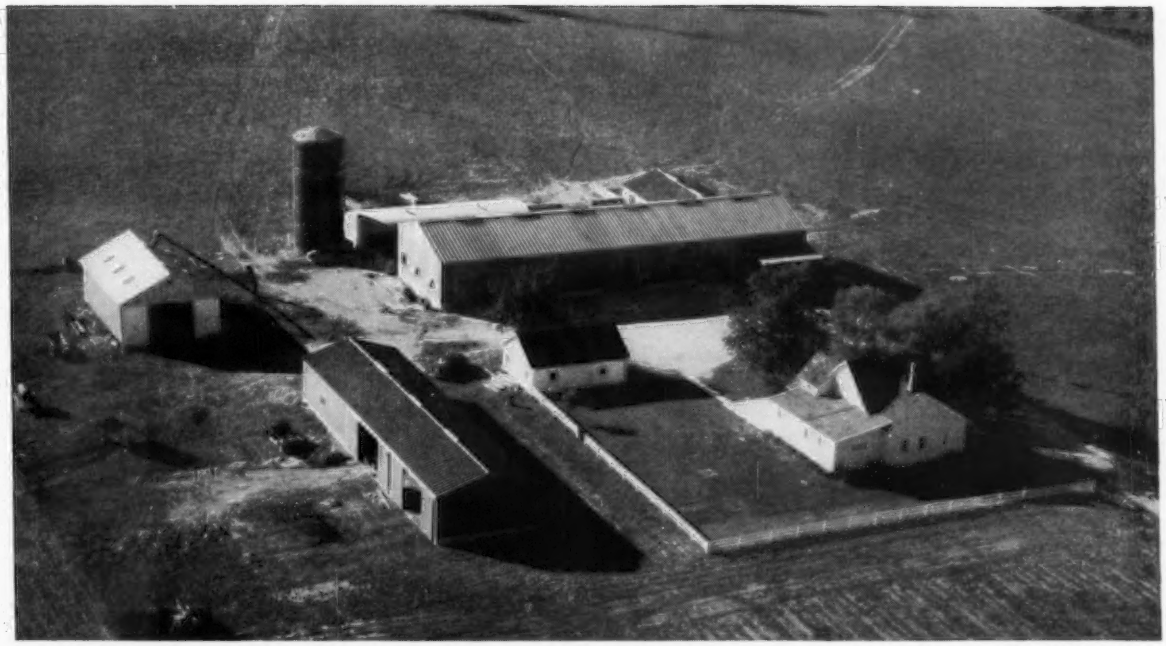


Fig. 5. Flow system with impermeable layer near phreatic surface.



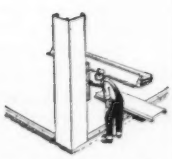
Aerial view of Freeman Farm, Muncie, Indiana. Durable, weather-tight, fire-resistant Armco Steel Buildings include the main barn, implement shed, maternity ward and lean-to housing the milk room.

Back in business fast after a fire!

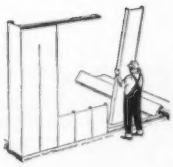
How easy-to-erect, fire-resistant Armco Steel Buildings cut construction time, costs and insurance premiums on this Indiana farm

When their dairy barn burned, Ernest and Vernon Freeman of Muncie, Indiana, compared costs and advantages of several types of construction. They decided upon Armco Steel Buildings. The main barn, 40 x 132 x 14, was erected in only 15 days by the Freemans and farm labor, under the direction of an Armco representative. The implement shed and shop, 28 x 100 x 12, was erected by a contractor. The whole project, which also included a 12 x 22-8 x 8 lean-to milk room and a 28 x 42-8 x 8 maternity ward, was completed exactly nine weeks after the fire. Quickly and at low cost, the Freemans were back in business with durable, weather-tight, fire-resistant buildings requiring a minimum of upkeep — and lower insurance premiums.

Fast, low-cost, easy erection is a feature of all Armco Steel Buildings. The reason: precision-made Armco STEELOX® Panels come ready for assembly. Quickly locked together and then bolted top and bottom, they provide a rigid structure that doesn't crack, warp or rot. Armco Steel Buildings are available in hundreds of shapes and sizes to meet floor requirements from 25 sq. ft. up for farm uses. Erection can be done by the Armco Dealer, farm workmen, or contractor's crew. For details, send coupon.



One man can easily handle Armco STEELOX Wall Panels. They fit together for structural support and finished exterior. Nothing to nail; one bolt fastens each section to the base.



Window and door openings are no problem. Short wall panels are used in place of regular panels. They are set in place and fastened the same as other panels to frame the opening.

Armco STEELOX Roof Panels are set in place and held securely by plate and ridge construction. Buildings have permanence, but can be dismantled and re-erected in another location.

ARMCO DRAINAGE & METAL PRODUCTS, INC.
537 Curtis Street, Middletown, Ohio

Send me information on Armco Steel Buildings for farm use.

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Address _____ *Town* _____

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ARMCO STEEL BUILDINGS

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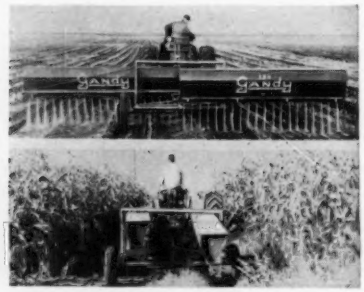
For more facts circle No. 75 on reply card

Folding Spreader-Seeder

E. S. Gandrud Co., Owatonna, Minn., has announced a new 20-ft wide, high-speed, spreader-seeder that quickly folds to less

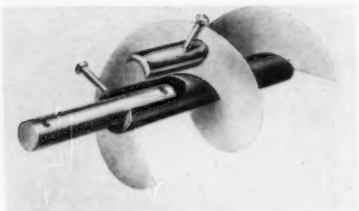


than 8 ft in width for highway travel. The new unit covers a wide swath in the field, yet provides ease in transporting over narrow country roads, bridges, or on paved highways. It holds over one ton of fertilizer using either bulk or bag fertilizer. Two hoppers make it possible to use this spreader for application of mixed fertilizer or the application of two straight elements, one from each hopper.

(For more facts circle No. 4 on reply card)

Screw Conveyor Components

Link-Belt Co. has added new related ball bearing equipment to its screw conveyor component line. Designed to fit new or

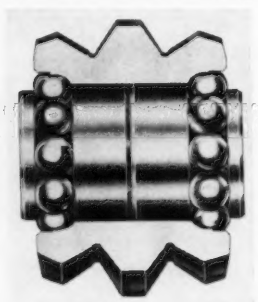


existing screw conveyors the new equipment includes a quick-change conveyor screw (illustrated), single and double ball bearing trough ends, new ball bearing hanger, ball and roller bearing enclosed countershaft ends, and completely enclosed single reduction helical "Motogear."

(For more facts circle No. 5 on reply card)

Roller Tooth Bearing

The Marlin-Rockwell Corp. has introduced new roller tooth ball bearings, designed for use in the manual steering mech-

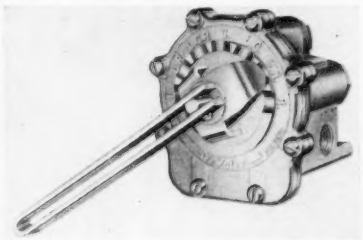


anism of automobiles, trucks and tractors. The profile of the bearing outer ring permits it to engage a worm gear on the steering shaft. This type of bearing can be adapted to other applications.

(For more facts circle No. 6 on reply card)

Spray Control Valve

Spraying Systems Co., Bellwood, Ill., has introduced a new TeeValve for selective spray control in boom spraying. The new valve may be mounted within easy reach from the tractor seat. Seven indexed settings



permit control of spraying with left, center or right boom sections, or any combination of these three sections. An outlet is provided for an auxiliary spray gun and connections for pressure gauge and pressure relief valve.

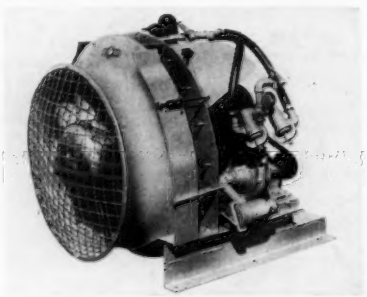
Selection of position is made with the lever down and valve remains shut-off during this step. Once selection is made, valve is turned on simply by raising lever handle. As a result chemicals are saved in spraying while turning lever or valve to desired setting. This also permits shut-off without changing setting of selected spraying position. The valve is made in aluminum and stainless steel for use with practically all standard farm chemicals.

(For more facts circle No. 7 on reply card)

Air-Blast Sprayer Power Kit

Besler Corp., 4053 Harlan St., Emeryville, Oakland 8, Calif., has introduced a new do-it-yourself power package for air-blast sprayer construction.

The power package is a complete air-blast sprayer—less tank and trailer—and includes

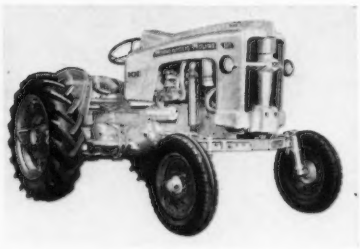


a 4-cylinder Wisconsin air-cooled engine, a 30-in axial fan (28,000 cfm) a 50-gpm centrifugal pump, valves and strainers, plus a geared unit for tank agitation. The package unit can be attached to an old tank and trailer unit, a tank and trailer built to specifications by a local welding shop, an old pick-up truck, or the grower's own rig.

(For more facts circle No. 8 on reply card)

Ten-Speed Tractor

Minneapolis-Moline Co., Minneapolis 1, Minn., has introduced its new model 335 Utility. Features include 10 forward and

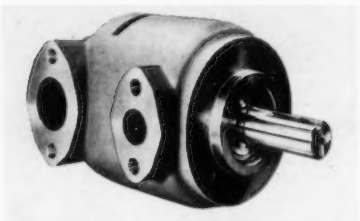


two reverse speeds with Ampli-Torc, power steering, and hydraulic 3-point hitch control of implements. The new model is rated at an estimated 35 belt hp and 30 drawbar hp.

(For more facts circle No. 9 on reply card)

2000-PSI Vane Pump

Denison Engineering Div. of the American Brake Shoe Co. has announced a new series of balanced vane hydraulic pumps for



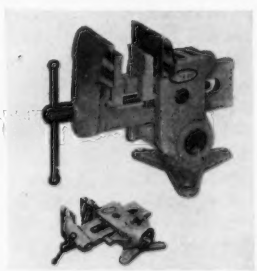
continuous 2000 psi service. Pumps are offered in this series supplying rated deliveries of up to 100 gpm at speeds up to 1800 rpm. The pump is available with either clockwise or counterclockwise shaft rotation.

Two bolt threaded flanges are provided as standard equipment but four bolt hydraulic connections are available. The pump may be face, foot or flange mounted in any of four positions on its mounting bracket. The suction inlet port can be assembled in many selected positions with regard to the pressure delivery port.

(For more facts circle No. 10 on reply card)

New Workshop Tool

The Will-Burt Co., Orrville, Ohio, has announced production of a new workshop tool called the Versa-Vise. The new vise is especially handy in shops where models and



templates are made. It locks automatically in any position as the jaws are tightened. It turns 360-deg either way and can be used standing or laid flat. The jaws are 3½ x 2½ in in depth with a 5-in jaw opening. Removable pipe jaws are included.

(For more facts circle No. 11 on reply card)

(Continued on page 190)

The NEW No. 110 MANURE SPREADER

A completely new spreader built for power livestock farming

THESE COST-CUTTING FEATURES MODERNIZE MANURE HANDLING

- ★ Thorough shredding: low, wide, uniform front-end spread — with 3 turbine-type slingers.
- ★ Large loading area. Unobstructed loading from both sides and rear.
- ★ Low, downward delivery and controlled placement keep operator and spreader much cleaner.
- ★ One lever spread control — 2 to 14 loads per acre.
- ★ Fully shielded, PTO-driven, roller chain drives.

To livestock farmers, the new Allis-Chalmers No. 110 power-driven *front-end delivery* Manure Spreader brings a new standard of efficiency in the handling of manure.

In developing this product, Allis-Chalmers engineering has introduced a new concept of . . .

- **Fast, Easy Loading**
- **Full Shredding Action**
- **LOW Spreading Uniformity**

. . . in a PTO-driven, 110-bushel spreader that also includes the advantages of dependable operation and long life.

Completely different in design and performance, the No. 110 has been exhaustively field-tested over a period of years.

Once again, engineering leadership brings new ease and efficiency to one of farming's most necessary . . . and difficult . . . tasks.

ALLIS-CHALMERS, FARM EQUIPMENT DIVISION, MILWAUKEE 1, WIS.

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Engineering in Action

***LISTEN TO** the National Farm and Home Hour every Saturday on your NBC radio station.*

For more facts circle No. 76 on reply card

. . . New Products

(Continued from page 188)

No-Shift Reversing Clutch

Funk Aircraft Co. has introduced no-shift reversing in a new torque converter transmission. There is no clutch or gear shifting. A single throttle lever, foot or hand operated, changes both direction and speed of travel. The Revers-O-Matic drive is adaptable to any type of operation involving change in direction of movement, either forward and reverse, or lift and lower, on equipment with engines up to 250 cu in displacement.

(For more facts circle No. 12 on reply card)

Drawbar Clevis Grab Hook

Midland Industries, Inc., Cedar Rapids, Iowa, has introduced a new tool for a quick hookup of towing chain for tractor drawbars. The 7-in grab hook is said to fit all tractor drawbars, front or back, up to and

including drawbars 1⅛ in thick, and can be used with any chain up to 7/16 in. It can be used for towing logs, grain bins, corn cribs, poultry and hog houses and for pulling fence posts with the tractor hydraulic lift.

(For more facts circle No. 13 on reply card)

Long and Low Burr Mill

Knoedler Manufacturers, Inc., Streator, Ill., has announced a new burr mill lateral auger that has low overall height, and at the same time has a high discharge height. Low clearance allows the mill to slip under a barn or crib doorway easily, while the higher discharge permits loading of high trucks, wagons, bins and self feeders. The 4-ft lateral auger is geared to the 8-ft high vertical auger. This new type elevator is available for all new and most older model Knoedler mills.

The entire auger assembly swings 360 deg by means of a handle attached to the vertical auger. Lateral augers with lengths up to

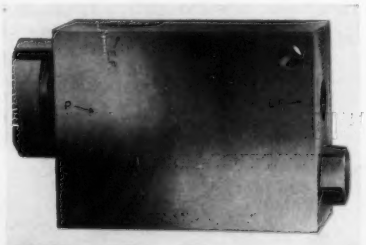
20 ft for stationary burr mills are also available. Other new features of the mill include the "hi-low" drive speed changer, an optional item which will increase or decrease the speed of the mill approximately one-third. This reportedly enables larger tractors to power a capacity of even more than the standard output of up to 300 bu per hour of ear corn. Similarly, by reducing speed, a small tractor can handle the mill at a reduced output.

Also, announced are a new automatic conveyor for feeding ear or shelled corn into the mill and a new crib drag, both powered from the mill.

(For more facts circle No. 15 on reply card)

Hydraulic Flow Divider

New Products Corp., Skokie, Ill., has developed a new hydraulic flow divider that can be adjusted to control the flow over a



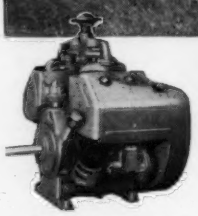
wide range from 10 to 95 percent. It also has a built-in relief valve that will pass the oil back to the sump when the peak pressure setting of the secondary flow is reached.

The flow divider is so designed that when the pressure of the primary operation begins to build up, the flow to the secondary operation begins to decrease. This means that on a fork truck for instance, no power in lifting will be sacrificed to power steering.

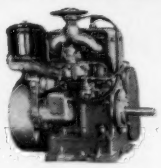
(For more facts circle No. 14 on reply card)

(Continued on page 192)

WHY YOUR COMBINE or BALER SHOULD BE WISCONSIN-POWERED



This is the 4-cylinder, V-type Wisconsin Air-Cooled Engine used extensively on leading makes of combines and the larger balers.



Several leading makes of Balers are now powered by this compact, powerful Wisconsin 2-cylinder engine, delivering up to 15 hp.

MORE CAPACITY—You can run your equipment at full capacity at all times without shifting gears because maximum ground speed can be maintained with Tractor Throttle Control.

FASTER—You cover more acreage per day because the tractor ground speed does not affect the uniform, efficient operation of the equipment. The Wisconsin Engine carries the operating load.

BETTER—Whether working in flat or hilly fields, light or heavy crops, on rough terrain, going around corners . . . your Wisconsin-powered equipment operates at top efficiency.

SAFER—Equipment individually powered by Wisconsin Engines eliminates the possibility of accidents caused by operator coming in contact with unshielded PTO when stepping off tractor.

EASIER—You operate your equipment with less fatigue and "time out" when a Wisconsin Engine carries the load because gear-shifting and operating tension are reduced to a minimum. You get more work done.

CHEAPER—A smaller tractor can be used to pull your Wisconsin-Powered equipment, releasing your more expensive, larger tractor for heavier work. This should result in worthwhile savings in tractor operating costs.

These are some of the reasons why leading builders of Combines and Balers include Wisconsin Heavy-Duty Air-Cooled Engines as original equipment . . . reasons why you, too, should specify Wisconsin-powered machines. Write for Bulletins S-195, 198 and 207 covering the complete line, with Authorized Service Station directory.

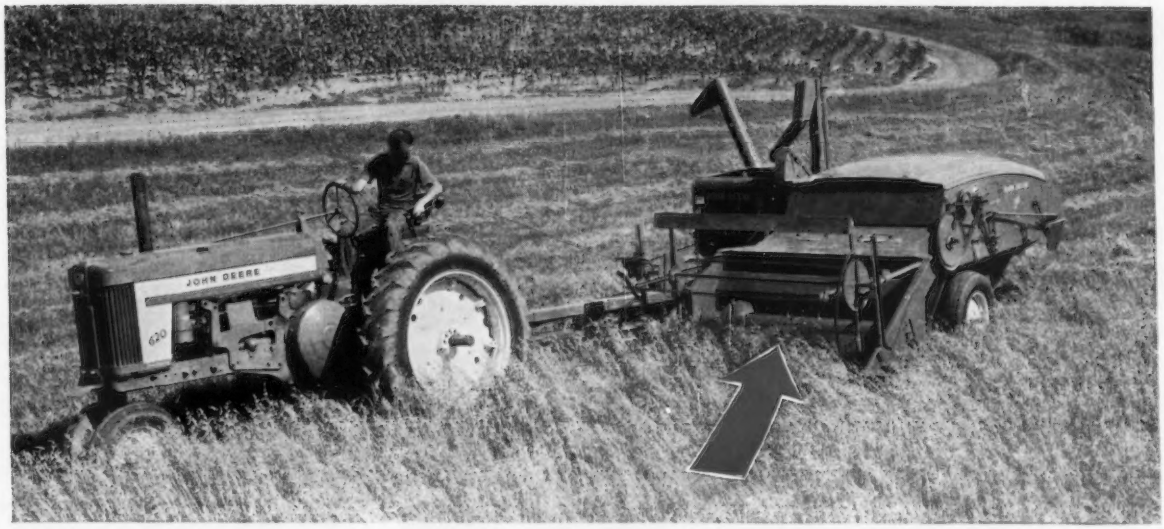
WISCONSIN MOTOR CORPORATION

World's Largest Builders of Heavy-Duty Air-Cooled Engines

MILWAUKEE 46, WISCONSIN

For more facts circle No. 51 on reply card

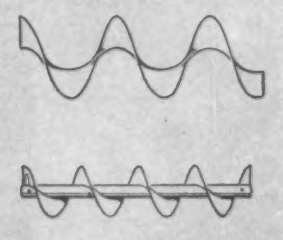
How LINK-BELT makes it easy to **work augers into your design**



THIS JOHN DEERE COMBINE incorporates one of the many types of Link-Belt augers designed for farm machinery.

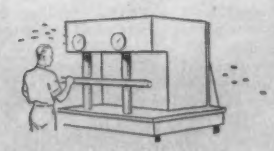
WHERE augers are a vital part of any equipment, here's the sure way to better equipment design. Link-Belt augers are available in a full range of diameters, gauges and pitches . . . in any suitable metal to meet your most exacting requirements. And they're simple and compact, accurately made to insure dependable operation.

For any design problem involving augers ask the Link-Belt office near you for engineering assistance.



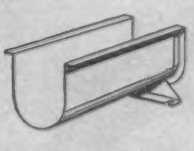
SELECTED FLIGHTING for all your auger needs. Helicoid, sectional or a range of other types are available in the metal and finish best suited for your design.

SIMPLICITY OF CONSTRUCTION and sturdy design of Link-Belt augers provide dependable, efficient operation on your machine. One basic assembly — no other moving parts to break down.



YOUR CHOICE OF METALS answers your requirements for handling corrosive or abrasive materials. And Link-Belt uses only specially selected steels.

ENGINEERING SERVICES. Our auger specialists will help to analyze your special needs . . . integrate all elements of your design for overall system efficiency.

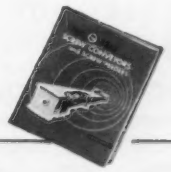


ALL COMPONENTS — conveyor screws, collars, couplings, hangers, troughs, trough ends, flanges, drives—are available for every design.

LINK-BELT

FARM MACHINE AUGERS

Get in touch with the nearest Link-Belt office for your copy of Screw Conveyor Data Book 2289 . . . today.



14,521

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville (Sydney), N.S.W.; South Africa, Springs. Representatives Throughout the World.

. . . New Products

(Continued from page 190)

New Mower Offers Three Hookups

New Holland Machine Co., New Holland, Pa., has announced three new mower models that offer a full choice of fully-mounted, semi-mounted and trail-type mowers on the same basic machine.

The Model 45 hooks up without tools to tractors with 3-point hookup or 2-point fast hitch. A built-in jack stand permits hooking up or parking without blocking. The Model 44 has a universal hitch for attaching to most tractors with only one set of irons. The Model 46 hitches and unhitches with simple one-point trailer hitch. It is completely supported by standard 15-in wheels.

Features include improved hold-down clips that ride over both the front and rear of knife blades to prevent the crop from wedging between knives and guards. For

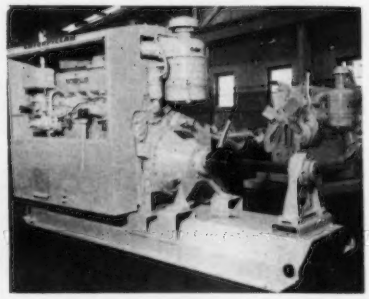
added sturdiness, a double-hinged connection is used between inner shoe and support. The support is rolled armor-plate steel which is said to reduce weight and to allow it to float over uneven ground easily. A full-length under-skid prevents crops from wrapping around the flywheel. This serves the double purpose of protecting against damage from surface objects.

(For more facts circle No. 16 on reply card)

Base for Electric Sets

Caterpillar Tractor Co., Peoria, Ill., has introduced a new type of wrap-around base and fuel tank combination for use with its diesel power units and electric sets.

The new bases have been designed for use with all Caterpillar engines and electric sets from models D311 through the D342. Models presently in production include extended and short base versions for D337 (series F) and D326 (series F) engines, a



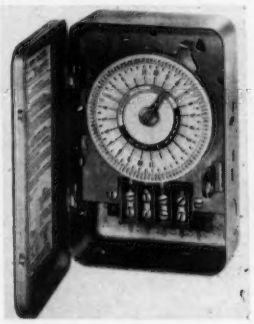
short base model for the D318 engine and electric set bases for D311 and D315 diesel electric sets. Other models will be added in the near future.

The new bases will replace the steel channel models formerly used. Primary advantage of the new bases is said to be the ability to withstand the stresses and strains of skidding and dragging. Extreme strength and rigidity enable them to resist the bending, flexing and other distortions to which power units used in the field are frequently subjected.

(For more facts circle No. 17 on reply card)

New Intermittent Time Switch

International Register Co., 2620 W. Washington Blvd., Chicago 6, Ill. has introduced a new line of time switches for controlling on-off intermittent cycles of 15 minutes. Known as the intermatic series T960 time switches, the company recommends their use for controlling automatic poultry feeders, barn ventilating fans, hay driers, water



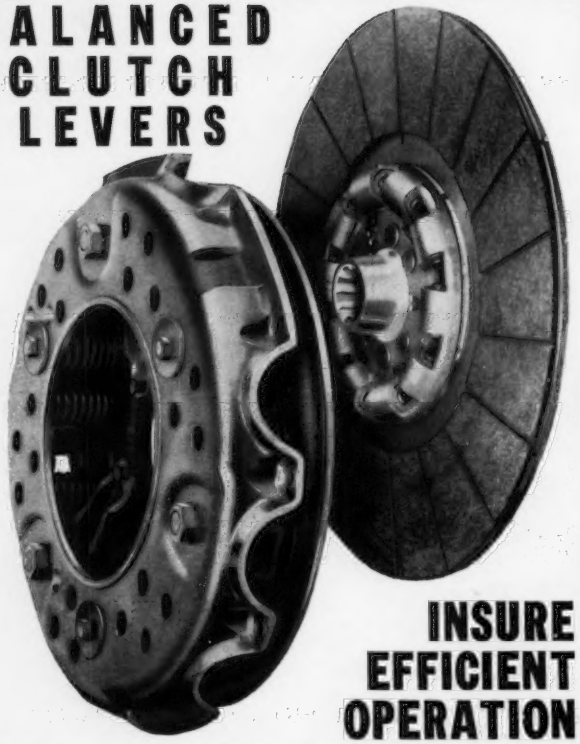
pumps, and other applications requiring intermittent operation.

The new switches feature a snap-out mechanism; a black on yellow time dial for good visibility, and a drawn-steel case with conveniently located knockouts on bottom, back and sides. Units are available in 125 and 250-volt models.

(For more facts circle No. 18 on reply card)

ROCKFORD

BALANCED CLUTCH LEVERS



Small Spring Loaded

Heavy Duty Spring Loaded

Oil or Dry Multiple Disc

Heavy Duty Over Center

Power Take-Offs

Speed Reducers

INSURE EFFICIENT OPERATION

The release levers in ROCKFORD clutches have been newly designed and are accurately balanced—so necessary in present day *high-speed, high-torque* engines. This is just one of several advantages ROCKFORD equipped motor vehicles feature in their late models.

SEND FOR THIS HANDY BULLETIN
Gives dimensions, capacity tables and complete specifications. Suggests typical applications.

ROCKFORD Clutch Division BORG-WARNER

1325 Eighteenth Ave., Rockford, Ill., U.S.A.

Export Sales Borg-Warner International — 36 So. Wabash, Chicago 3, Ill.

CLUTCHES

For more facts circle No. 59 on reply card

MANUFACTURERS' LITERATURE

Oil Filters

Caterpillar Tractor Co.—A brochure, DE 629, entitled A Brief Case for Cat Filters, discusses the requirements of effective filtration and how oil filters help increase engine life. The brochure is illustrated and is available in French, Spanish and Portuguese.

(For more facts circle No. 19 on reply card)

Sprinkler Irrigation Guide

W. R. Ames Co. — A 16-page booklet which covers some factors to consider when purchasing a sprinkler system. Included in the booklet are many pointers regarding sprinkler system requirements, design and operation. Pumps and power units are also discussed.

(For more facts circle No. 20 on reply card)

Modern Farming — 1957 Edition

Deere & Company — This 92-page booklet pictures and describes most of the tractors and farm equipment made by the company. It can be a helpful editorial reference on the operation and use of various farm implements, and a source of modern farming photographs.

(For more facts circle No. 21 on reply card)

No-Skive Hydraulic Hose Fittings

Parker Appliance Co., Tube and Hose Fittings Div. — Catalog 4433 describes reusable hoze-lok fittings for rubber-covered double-wire braid hose for high-pressure service. The 4-page catalog includes charts listing complete specifications of available fittings.

(For more facts circle No. 22 on reply card)

All-Crop Harvester

Allis-Chalmers Mfg. Co.—An 8-page brochure (TL-1662) which covers the company's new super 100 self-propelled all-crop harvester. It explains and illustrates the new features of this harvester, such as optional power steering, folding delivery spout, new control panel, new radiator and higher intake screen, new high-clearance reel drive, etc.

(For more facts circle No. 23 on reply card)

High-Pressure Hose Couplings

Le-Hi Division of Hose Accessories Co.—This 8-page bulletin No. 115, describes and illustrates the company's heavy-duty high-pressure hose couplings. It covers applications of high-pressure air, steam, gas, hydraulic, liquid, etc., used in construction, mining, contracting, petroleum refining, and in general industry.

(For more facts circle No. 24 on reply card)

Gears, Transmissions and Machined Parts

New Process Gear Corp. — The 24-page catalog describes a complete line of gears, transmissions and other machined parts that are manufactured by the company. Pictures illustrate the company's engineering and designing facilities.

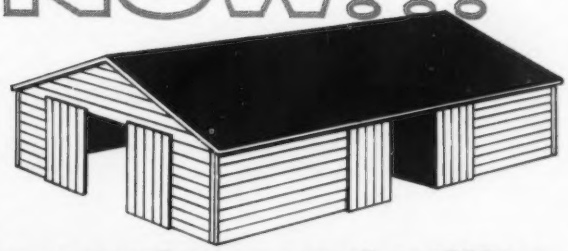
(For more facts circle No. 25 on reply card)

Engineering Instruments

Custom Scientific Instruments, Inc.—Catalog No. CS-56 illustrates and describes instruments and equipment for research, control and production. The 8-page catalog includes abrasion testers, physical testers, thickness, compression and recovery testers, and precision checking and scientific instruments.

(For more facts circle No. 26 on reply card)

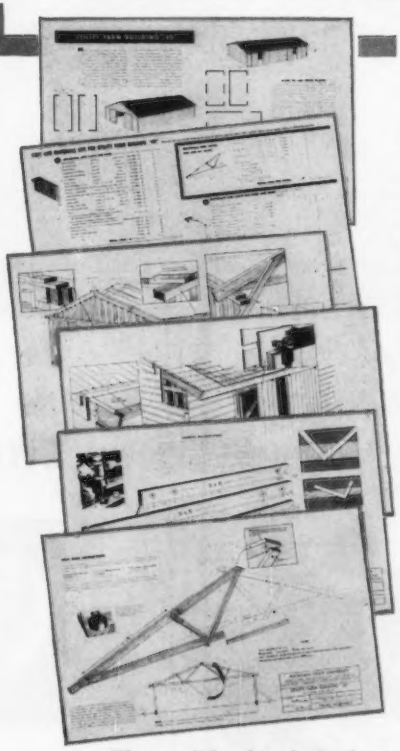
NOW...



an engineered utility building of WOOD!

Designed by agricultural engineers for the progressive, modern farmer, this is the building that combines all the advantages of wood construction in a practical package.

EASY-TO-FOLLOW PLANS COVER EVERY STEP OF ESTIMATING, MATERIAL ORDERING, CONSTRUCTION



Page 1—FOUNDATION CHART
Using this page, the farmer plans all details of the building. The foundation sketch becomes the basis for estimating costs and materials.

Page 2—COST ESTIMATION
Detailed forms cover every phase of construction. The local retail lumber dealer figures the quantities and prices of lumber and materials.

Page 3—FRAMING DETAILS
Diagrams show the placement of trusses, door framing and other details of good construction.

Page 4—FINISH DETAILS
Detailed drawings show how to apply roofing, how to place siding, how to hang doors and finish corners.

Page 5—TRUSS MEMBERS
Detailed instructions show how to construct the simple truss.

Page 6—TRUSS ASSEMBLY
This page describes the installation of ring connectors, lists loads, stresses and lumber grades and shows how the truss is put in place.

The retail lumber dealer in your area will be glad to discuss any details of this building with you. Depending on the farmer's requirements, he will handle all details from planning to actual construction, or will furnish all materials, with or without pre-assembled trusses.

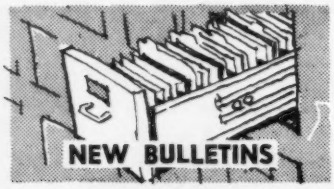
For further information on this versatile, utility building see your lumber dealer or write to:

West Coast Lumbermen's Association

1410 S. W. Morrison St., Portland 5, Oregon

Douglas Fir • West Coast Hemlock
Western Red Cedar • Sitka Spruce

For more facts circle No. 57 on reply card



The Penn State Solar Poultry House, by G. O. Bressler and H. V. Walton. Pennsylvania State University Agricultural Experiment Station, University Park, Pa. Progress report 162.

This report gives a brief description of results obtained with the solar poultry house and describes house features including insulation, solar heat utilization, ventilation and equipment arrangement. A set of working drawings for the construction of this house and a bill of materials are included in this progress report. Copies are available by writing to H. V. Walton, agricultural engineering dept., Pennsylvania State University or W. Everett Eakin, Libbey-Owens-Ford Glass Co., Toledo 3, Ohio.

Available, also, from Libbey-Owens-Ford Glass Co., are bulletins: **Solar Housing For Swine** by J. S. Boyd and J. A. Hoefer, Michigan Agricultural Experiment Station, (8 pages) Article 39-36, November, 1956, and **A Survey of Solar Poultry Houses** by G. O. Bressler, for LOF Glass Co. (8 pages).

Harvesting Your Milk Crop, by Charles W. Turner, University of Missouri, (Columbia). Published by Babson Bros. Co., Chicago, Ill.

The 18-page booklet contains illustrations and diagrams to aid modern dairymen in doing a better job of milking. It includes some mechanical and physical factors which can limit a dairy income, and explains what goes on inside cows, the ways the cows react, just what gets more milk, and how machine milking affects cows.

Copies of this booklet are available without charge from Babson Bros. Co., 2843 W. 19th St., Chicago 23, Ill.

Economic Efficiency in Plant Operations with Special Reference to the Marketing of California Pears, by B. C. French, L. L. Sammet and R. B. Bressler. *Hilgardia,* vol. 24, no. 19 (July, 1956).

This report develops a theoretical framework and methodological approach to production plant cost studies and applies them to an analysis of production efficiency in packing fresh California pears. A framework is developed by modifying economic theory of a firm to reflect operating characteristics of most production plants. A method of cost synthesis is presented in which engineering studies of labor and equipment utilization on specific plant operations, performance data, and analyses of accounting record data are used to estimate input-output data.

Economics of Irrigation in Michigan, by C. R. Hoglund, E. H. Kidder and K. A. Vary. Reprinted from the Quarterly Bulletin of the Michigan Agricultural Experiment Station, East Lansing, vol. 39, no. 19 (November, 1956).

This 21-page paper presents the results of a survey made in cooperation with 176 farmers irrigating from less than one to over 100 acres. Items included are the effect on yield, investment per farm, investment in wells, distribution systems, factors affecting cost, factors affecting net income and typical farm systems.

Farm Ponds — Their Construction and Management, by H. D. Ayers and A. de Vos. Ontario Department of Agriculture, Toronto, Canada. Bulletin 515 (July, 1956).

Farm ponds, properly constructed, serve a number of purposes as this 23-page bulletin points out. Ponds may supply water for livestock, domestic use, fire protection, spraying and irrigation. It is also noted that they can be an asset for recreation, fish and wildlife production, and beautification. Various types of ponds and their construction are illustrated by pictures and tables of dimensions. A section is included on the management of the pond for fish and wildlife.

Copies of the following bulletins are available to ASAE members by writing to Harry F. Blaney, Western Soil and Water Management Section, ARS, SWCRB, USDA, 1505 Post Office Court House, Los Angeles 12, Calif.: **Research on Evaporation and Evapotranspiration in the United States** by R. K. Linsley, H. F. Blaney, G. E. Harbeck and M. A. Kohler; **Evapotranspiration Measurements in Western United States** by H. F. Blaney; **Evaporation and Evapotranspiration Investigations in the San Francisco Bay Area** by H. F. Blaney and D. C. Muckel; and **Evaporation and Evapotranspiration Studies, United States Department of Agriculture in the Pacific Southwest** by H. F. Blaney.

NIAE Bulletin. The following bulletin has been received recently from the National Institute of Agricultural Engineering, Wrest Park, Silsoe, Bedfordshire, England:

Mower Parts Made to British Standard 1562:1949—No. 120/A. The bulletin reports on a test to assess the performance in the field of mower fingers and knife sections made in accordance with B.S. 1562:1949.

By Boom

SPRAYING SYSTEMS TeeJet SPRAY NOZZLES

Choice of over 400 interchangeable orifice tips for exact control in farm spraying.

Write for Catalog 30

By Boomjet

For broadcast spraying of grains and grasses... and spraying of nitrogen fertilizer solutions. Sprays up to 66 feet wide.

Write for Bulletin 71

SPRAYING SYSTEMS BoomJet SPRAY NOZZLES

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from SPRAYING SYSTEMS CO.

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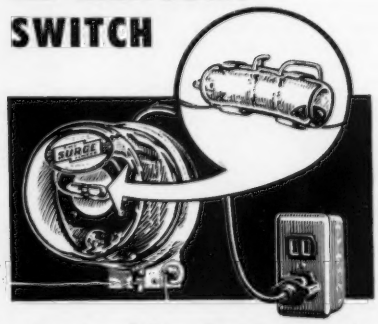
Surge FENCER

The Stock Controller with the MERCURY SWITCH



Backed by Organized Surge Service

SEE YOUR SURGE DEALER

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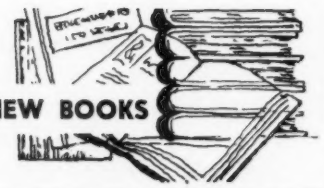


Can We Solve the Farm Problem?: An Analysis of Federal Aid to Agriculture by Murray R. Benedict. Cloth, 6 x 9 inches, xix + 601 pages, indexed. Published by the Twentieth Century Fund, 330 W. 42nd St., New York 36, N. Y. $5.00.

The author discusses topics on parity, price supports, government storage of surplus commodities; what the effect of these and other "emergency" farm programs have had on the economy, on the export market, and on the farmer himself; and the program for the future. It also gives an overall view of the government's relation to agriculture.

This book offers the recommendations of a special Committee on Agricultural Policy appointed by the Twentieth Century Fund to consider steps that should be taken, both in the interests of farmers and of the country as a whole.

The New Revolution in the Cotton Economy, by James H. Street. Cloth, 6 x 9 inches, xvi + 294 pages, indexed and illustrated. Published by The University of North Carolina Press, Chapel Hill, N. C. $5.00.

This book is a history of mechanization in the cotton economy and is a contribution to better public understanding of farm mechanization and its social effects on southern farm welfare. The author traces the history of cotton growing, the effect of two world wars, out migration of the Negro from the South, and the competition by synthetic products. He explains why technological advance in American cotton production was delayed and discusses the men and companies who battled against seemingly impossible difficulties in perfecting and marketing machines which would eliminate the human drudgery in producing the crop.

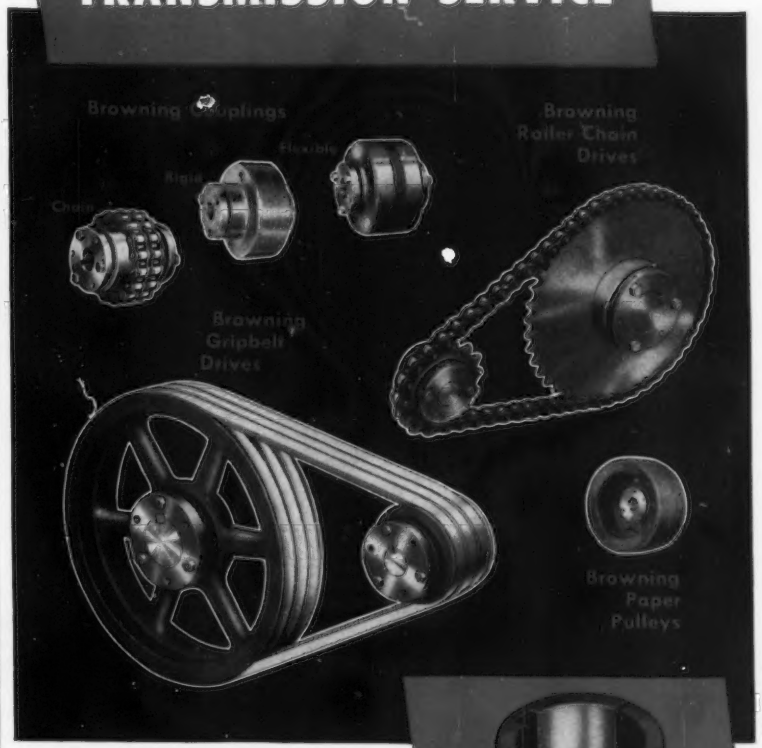
The book lists reasons for the recent acceleration in the process of technological change within the Cotton Belt and considers some of the economic and social implications of a continuation of the trends now visible.

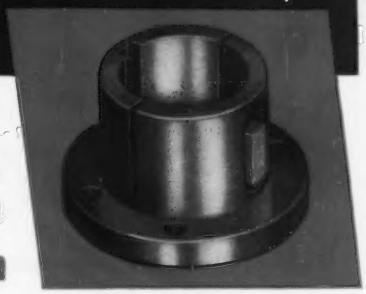
Elements of Engineering Materials, by Charles P. Bacha, Joseph L. Schwalje and Anthony J. Del Mastro. Cloth, 6 x 9 inches, xiii + 494 pages. Illustrated and indexed. Harper & Brothers, 49 E. 33rd St., New York 16, N. Y. $6.50.

This book is an introductory text on the elements and applications of engineering materials and is written for students in all branches of engineering. Engineering materials including wood, cements, plastics, rubber, soils, metals, fuels and lubricants have been considered, as well as the latest practices available in each field. Chapters on the structure of metallic materials, behavior under load, corrosion and its prevention, and the shaping and forming of metallic materials have been included.

Each topic is given a brief, but fundamental treatment. Subjects common to all branches of engineering are in the early chapters to provide a background for later discussion of such topics as metals, corrosion, cementing, etc. A list of references for further study is included.

Browning - THE ONLY COMPLETE POWER TRANSMISSION SERVICE





Using One Interchangeable Bushing System

From this single source you can select the most efficient and economical power transmission components for any farm equipment, while standardizing on one-type bushing. For Browning manufactures a complete integrated line of sheaves, sprockets, paper pulleys and couplings; all using Browning's exclusive *malleable* split taper bushing that grips the shaft with positive clamping force, yet mounts and removes with ease. Thousands of stock size and bore combinations, ready to use. Plus a full complement of roller chain and V-belts, including Double V, Griplink and Griproll belting. Investigate today! Ask for complete information and copy of descriptive Catalog GC101. **Browning Manufacturing Company, Maysville, Kentucky.**

Browning POWER TRANSMISSION EQUIPMENT

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Under operating pressures bushing heats and releases stored lubricant which is reabsorbed by bushing when chain is idle. Cycle continues for life of chain.

FORGET MAINTENANCE?

Just about . . . WHITNEY SELF-LUBE AGRICULTURAL CHAIN *keeps farm equipment continuously operating without chain maintenance.* And it will outlast regular chain as much as 5 to 1 when subject to rugged field service in atmospheres ladened with dirt or moisture.

WHY? Because Whitney engineering has developed and proven by extensive field service, *exclusive* SINTERED STEEL CHAIN BUSHINGS . . . *prelubricated for life.*

HOW? The Whitney SINTERED BUSHING design provides strength exceeding all duty requirements. It provides surface film-oiling from the inside, in ratio to load during chain operation. When idle, the bushing reabsorbs its lubricant, this cycle continuing for the life of the chain. In addition to the self-lubricating feature, the chain design provides controlled clearance . . . cannot trap abrasive matter ruinous to chain life.

WHAT'S MORE . . . Whitney Self-Lube Ag Chain is completely interchangeable with A.S.A. Double Pitch Roller Chains. They are precision made of premium materials and engineered for all types of farm machinery.

Your customers profit by the time and money saving benefits of Whitney Self-Lube Ag Chain. Whitney nation-wide consultant engineering service is promptly available to assist in determining the chain best suited to your requirements. If you want results specify WHITNEY CHAIN. Write for free technical brochures.

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4	14	24	34	44	54	64	74	84	94
5	15	25	35	45	55	65	75	85	95
6	16	26	36	46	56	66	76	86	96
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1	11	21	31	41	51	61	71	81	91
2	12	22	32	42	52	62	72	82	92
3	13	23	33	43	53	63	73	83	93
4	14	24	34	44	54	64	74	84	94
5	15	25	35	45	55	65	75	85	95
6	16	26	36	46	56	66	76	86	96
7	17	27	37	47	57	67	77	87	97
8	18	28	38	48	58	68	78	88	98

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Anderson, Vernon L. — On duty with U.S. Army (Mail) R.R. 1, Box 96, Mabton, Wash.

Autry, William E. Jr. — Agr. engr., (SCS) USDA, Pampa, Texas (Mail) 712 N. Dwight

Avery, Bennet W. — Grad. student, temp. instr., agr. eng. dept., Pennsylvania State University, University Park, Pa.

Blackwelder, Ernest F. — Pres. and gen. mgr., Blackwelder Mfg. Co. (Mail) P.O. Box 808, Rio Vista, Calif.

Bratcher, Robert F. — Agr. engr., (SCS) USDA, Osceola, Ark. (Mail) 1105 W. Ford

Bruns, James E. — Distribution analysis section of sales dept., Ford Motor Co., Tractor & Implement Div., Birmingham, Mich. (Mail) R.R. 4, Box 114, Opelika, Alabama

Chudleigh, Clifford E. — Vice-president, Chudleigh Farms, Inc., Hockley, Texas (Mail) Box 4451, College Station

Cronin, Paul L. — Sales engr., Kelsey-Hayes Co., 3600 Military, Detroit 32, Mich.

Davenport, Robert E. — Assoc. editor, Hoard's Dairyman, Fort Atkinson, Wis.

Davidson, Jack T. — Civil engr., Illinois Division of Highways, Springfield, Ill. (Mail) 1132 W. Monroe

Engel, Clark C. — Owner, Engel Tile Base Co., R.R. 1, Palmyra, Mich.

Golombisky, Clarence—Owner, Tile Drainage Service, R.R. 2, Corunna, Mich.

Grether, Tobias — Owner, Grether Agricultural Equipment Co., R.R. 2, Box 182-A, Camarillo, Calif.

Gruben, Wayne E. — Engr. trainee, John Deere Spreader Works, East Moline, Ill. (Mail) 849 15th St., Moline, Ill.

Hahn, G. Leroy — Agr. engr., (AERB) USDA, Columbia, Mo. (Mail) Texacotown Trailer Court

Hamilton, Harry R. — Sales mgr., Willard F. Howland Co., Southampton, Mass. (Mail) 53 Hillcrest Rd., Glastonbury, Conn.

Hebner, Theodore J.—On duty with armed forces (Mail) R.R. 1, Tremont, Ill.

Hopkins, Elmer L. — Pres. and designer, Hopkins Mfg. Co., Saginaw, Mich. (Mail) 2145 W. Moore Rd.

Jedlicka, George R. — Grad. student, University of Illinois (Mail) 603 S. Elm, Champaign, Ill.

Kraft, Lowell E. — Partner, Kraft and Son, Pigeon, Mich. (Mail) Box 164

Lask, Kay V. — Grad. asst., Michigan State University, East Lansing, Mich. (Mail) 123 Louis St., Apt. 4

Legge, Travers — Farm bldgs. advisor, The Farmers Weekly, Hulton House, Fleet St., London EC 4, England

Leinhauser, Joe P. — Engr. trainee, product eng. dept., John Deere Ottumwa Works, Ottumwa, Iowa

Loop, James W. — On duty with the armed forces (Mail) Box 10442, Ft. Bliss, Texas

Manro, Joseph E. — Test man, John Deere Ottumwa Works (Mail) 123 N. Iowa Ave., Ottumwa, Iowa

Minzberg, Gedalia—Farm mgr., Tel Katzir, Post Jordan Valley, Israel

Nelson, John W. — Dir. of res., Michigan Blueberry Growers Assn., Grand Junction, Mich. (Mail) R.R. 1, Box 17

Netherton, James D. — Ext. agr. eng. spec., North Carolina State College, Raleigh, N. C.

Ohala, Dwight J.—Engr., Convair, Pomona, Calif. (Mail) 2222 High Moor Rd., Highland Park, Ill.

Rathbone, Ronald A.—Lecturer, Cambridge University Dept. of Estate Management, 74 Trumpington St., Cambridge, England

Rolfes, George A.—President, Rolfes Grain Aeration Co., 821 15th St., Boone, Iowa

Schaffer, Robert L. — Maintenance engr., Green Giant Co., Glencoe, Minn.

SwamyRao, Ajjampur A. — Student and grad. asst., agr. eng. dept., University of Illinois, Urbana, Ill.

Wise, William G. — Electrical dev. rep., Tennessee Valley Authority, Tupelo, Miss. (Mail) 417 Edney Bldg., Chattanooga, Tenn.

(Continued on page 202)

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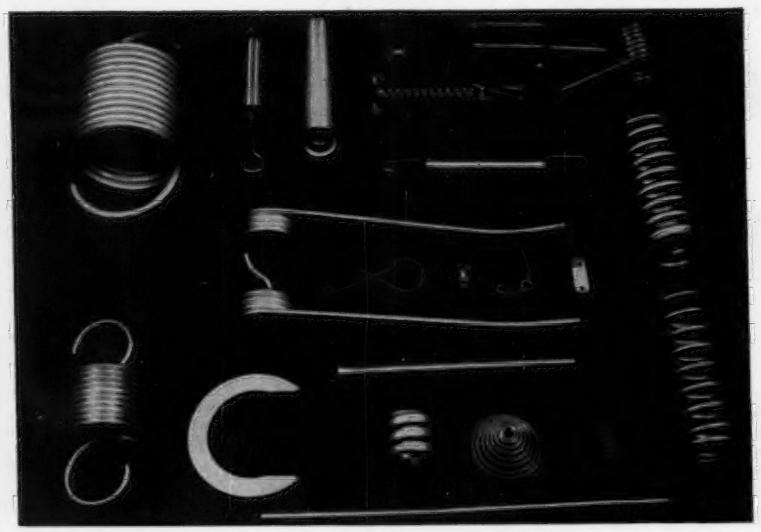

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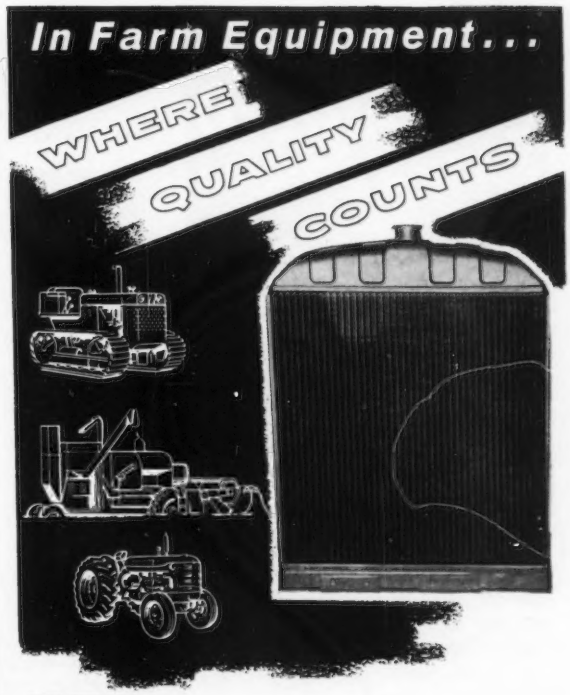

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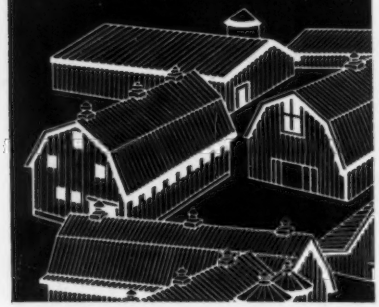

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. . . Applicants

(Continued from page 200)

Transfer of Membership

Davis, Sterling—Agr. engr., (ARS) USDA, P.O. Box 435, Chinook, Montana (Associate Member to Member)

Evans, R. C.—Sr. proj. engr., New Idea Farm Equipment Co., Coldwater, Ohio (Mail) 107 Ave. E, Greenville, Ohio (Associate Member to Member)

Kline, Gerald L.—Agr. engr., (AMS, MRS) USDA, Washington, D.C. (Mail) Agr. Eng. Dept., Kansas State College, Manhattan, Kans. (Associate Member to Member)

Peart, Robert M.—Instr. and res. assoc., University of Illinois, Urbana, Ill. (Mail) 6 Penn Ct. (Associate Member to Member)

Stermer, Raymond A.—Field sta. leader, (AMS) USDA (Mail) Agr. Eng. Dept., College Station, Texas (Associate Member to Member)

Whitney, Lester F.—Asst. chief engr., Wirthmore Div., Corn Products Refining Co., 49 Clinton St., Malden 48, Mass. (Associate Member to Member)

. . . Forum

(Continued from page 186)

materially from the slope of the water table. In that case, serious errors will not result from the substitution. Where h is large (Fig. 6), however, the gradients along the

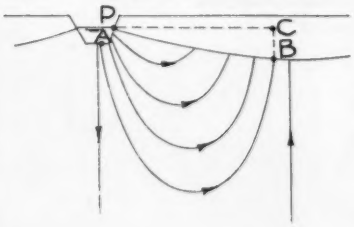

Fig. 6. Flow system with impermeable layer at great depth below phreatic surface.

streamlines are only a fraction of the slope of the water table, so that substitution of the latter for the former is not permitted (compare for instance the slope of the water table BC/PB with the actual gradient BC/AB). Therefore, the requirement that h be large and the substitution of the slope of the water table for the actual gradients, seem to be two conflicting items. A more detailed analysis of this problem has been presented by Hooghoudt (1)*, which in part is mentioned by van Schilfgaarde et al(2).

Perhaps the nearest analytical treatment of flow problems related to drainage and subirrigation has been presented by van Deemter(3). Both his and Hooghoudt's results indicate that as long as h is larger than about $W/4$, the impermeable layer can be considered absent ($h=\infty$). The position of the impermeable layer, or the quantity h, can only have a measurable effect on the flow system if $h<W/4$. In the article in question, however, the product h x permeability appears in the final equation 19. This means that it could be possible to compensate for any decrease in permeability P by a corresponding increase in h as far as ditch spacing is concerned, even if these increases are made after h has already entered the region where its actual value is no longer of practical importance with respect to effect on flow characteristics ($h>W/4$). The theoretical weakness of equation 19 can be demonstrated by evaluating W for a hypothetical subirrigation system in solid rock where the permeability is zero but h is infinite (or at least very large).

On page 103 of the article, first column, a number of requirements are listed for subirrigation to be "practical and successful." Since technically subirrigation can be practiced under any condition, the words practical and successful must refer to economical aspects. The requirements listed in the article point to large W-values, so that in most cases the thickness of the water-bearing material h will be small in relation to W. However, there are areas in the world, where the economic levels are different and feeder lines are spaced as little as 30 ft apart. Under those conditions, h does not have to assume very large proportions to prohibit the use of equation 19 of the article.

As an illustration, the following ditch spacings were computed with Hooghoudt's equation and equation 19 of the article in question:

$u=0.28$ in per day, $d=0.5$ ft, $h=20$ ft

Permeability	Ditch spacing according to Hooghoudt	Ditch spacing according to Fox et al.
0.0000068 ft per sec	23 ft	45 ft
0.00004 ft per sec	77 ft	110 ft

As could be expected, the spacings by Fox et al. are greater than those by Hooghoudt, especially at the higher h/W ratios.

Conclusion

Summarizing the importance of the two problems in the design of subirrigation systems, it appears that the first problem may lead to overdesigned systems if the equations by Fox *et al.* are used (actual d larger than d used in the equation), whereas the second problem may lead to underdesigned systems (actual gradients smaller than slope of the water table used in the equation). There may be cases where the two effects are in balance, so that satisfactory results with the equations of the article in question are not precluded.

A third comment refers to the statement "the Darcy equation of continuity" at the top of page 105, first column. This is a contradictio in terminis, since the Darcy equation only states that friction loss is proportional to flow velocity, whereas the equation of continuity merely expresses the incompressibility of the liquid and for two-dimensional flow is usually written as:

$$dV_x/dx+dV_y/dy=0$$

HERMAN BOUWER

Agricultural Engineering Dept.
Alabama Polytechnic Institute
Auburn, Ala.

References

1 Hooghoudt, S. B. Bydragen tot de kennis van enige natuurkundige grootheden van de grond. No. 7, The Hague, 1940.

2 van Schilfgaarde, Jan; Kirkham, Don; and Frevert, R. K. Physical and mathematical theories of tile and ditch drainage and their usefulness in design. Research Bull. 436, Iowa Agr. Exp. Sta., 1956.

3 van Deemter, J. J. Theoretical and numerical treatment of flow problems connected with drainage and irrigation. The Hague, 1950.

*Numbers in parentheses refer to appended references.

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POSITIONS OPEN — 1956 — SEPTEMBER — O-271-650, 305-651, 307-652, 292-653, 314-654, OCTOBER — O-330-655, 316-656. NOVEMBER O-252-657, 363-658, 365-660, 365-661, 365-662, 382-663. DECEMBER — O-374-664, 374-665, 384-666, 385-667, 388-668, 394-670, 393-671, 396-672, 401-673. 1957 — JANUARY — O-414-675, 416-676, 453-677, 8-701. FEBRUARY—O-14-702, 14-703, 23-704, 23-705, 23-706, 12-707, 28-708, 38-709.

POSITIONS WANTED — 1956 — SEPTEMBER — W-359-30. OCTOBER—W-315-31, 323-33, 328-34, 332-35. NOVEMBER — W-255-36, 379-37. DECEMBER — W-366-40. 1957 — JANUARY—W-405-42, 413-43, 419-45, 422-46, 420-48. FEBRUARY—W-364-47, 13-1, 33-2, 10-3.

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AGRICULTURAL ENGINEERS, also mechanical and electrical engineers, (several) for work in product research, design and development of farm tractors and construction equipment. Advanced design, product design, design analysis, research, stress analysis, vibration, lab and field testing. Large manufacturer. Midwest locations. Age 24-40. BS or MS deg in agricultural, mechanical or electrical engineering, with mathematics through calculus, and machine design courses. Farm background and design and test experience desirable but not essential. Ability to work with others, and interest in work on farm tractors and construction equipment. Variety of opportunities for advancement, on proof of ability to assume increased responsibilities. Salary open. O-52-711

AGRICULTURAL ENGINEER, assistant or associate professor rank, for teaching and research in power and machinery at an eastern land grant university and to be in charge of one phase of the teaching program in the department. Age under 50. MS deg in agricultural engineering. Teaching experience in an agricultural engineering department required. Experience in farm equipment industry also desirable. Interest in teaching and research. Ability to work well with staff members and representatives from industry. Excellent opportunity in expanding department, especially for work in cooperation with the farm equipment industry. Salary open. O-60-712

PROJECT ENGINEER for improvement and development of tillage, fertilization, and chemical spray equipment for sugar cane production in Hawaii. Degree in agricultural or mechanical engineering plus a minimum of 5 years experience essential. Family will be moved to Honolulu. Long vacation each three years plus other benefits. Salary open. O-45-713.

ASSISTANT PROJECT ENGINEER to assist in improvement and development of specialized field machinery for sugar industry of Hawaii. Degree in agricultural or mechanical engineering essential. Family will be moved to Honolulu. Long vacation each three years, plus other benefits. Salary open. O-45-714

GRADUATE ASSISTANTS (several) for research in any fields of agricultural engineering, in a New England land grant university. Arrangements can be made for teaching assistantships at the option of the individual. Research programs to meet individual needs, desires and abilities. BS deg in agricultural engineering or equivalent, with above average scholarship. Genuine interest in determining fundamental relationships basic to the development of improved farm equipment, structures, soil and water practices, and crop handling methods. Immediate openings, others at convenience of appointee up to September 15. Excellent opportunity to qualify for new staff positions in expanding department. Salary $2,000 plus tuition for one-half time. O-81-715

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HYDRAULIC ENGINEER for laboratory research on soil and water conservation structures for nation-wide application. Work includes planning and conducting experiments, analyzing data, and preparing research reports. Upper Midwest. BS deg in engineering. Hydraulic laboratory experience desirable. Usual personal qualification for public service research. Excellent opportunity for interesting and valuable experience in one of the best equipped hydraulic laboratories, and for professional recognition and advancement. Salary $6115 or $7035. (GS 5-9 or 11). O-70-717.

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. . . Members in News

(Continued from page 184)

Orson W. Israelsen, professor emeritus of irrigation and drainage at Utah State Agricultural College, and his wife have returned from a 50,000 mile trip to two dozen countries in Asia, Europe, and South Africa on a technical assistance mission.

Mr. Israelsen served as professor of irrigation and drainage at the University of Roorkee in India and later as consultant of drainage problems in Iran. In India, he organized a research project on control and pumping of ground water, and in Iran he inspected large areas of salt and alkali lands which were at one time productive but are now barren.

After leaving Iran, the Israelsens visited with irrigation engineers and agronomists in Baghdad, also the American University of Lebanon in Beirut. In Egypt they saw reclaimed land near Cairo, and after a short trip to Turkey, Greece and Italy they met Vaughn E. Hansen (professor at USAC) in Rome. They accompanied Mr. Hansen on a field study of irrigation and drainage problems in Angola, South Africa. On returning to Rome, they conferred with engineers of the United Nations' Food and Agriculture Organization.

Mr. Israelsen reports that technical assistance is of great value to the world and should be strengthened and expanded. He says that U. S. geologists and ground water engineers are making substantial progress in India and elsewhere. The value of free enterprise is becoming more and more understood in Asia as a result of United States' technical assistance program.

•

V. R. Hillman, who has been on leave from the Virginia State Soil Conservation Committee, resigned to continue his work with the Foreign Agricultural Service of the U.S. Department of Agriculture. He will be stationed in Djakarta, Indonesia.

•

Charles F. Cromwell, Jr. has been appointed assistant professor of agricultural engineering at the University of Missouri. He will do research work in irrigation and cotton mechanization at the Southeast Missouri Experiment Station. Formerly he was engaged in the farming and custom cotton picking business in Imperial Valley of Calif. He was also drainage engineer with the SCS his last year in Imperial.

•

Richard E. Crown has accepted a position with the New Idea Farm Equipment Co. in Coldwater, Ohio. Formerly he worked for the Detroit Harvester Co.

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Aluminum Co. of America 159
American Spring & Wire Specialty Co. 200
American Zinc Institute 202
W. R. Ames Co. 206
Armco Drainage & Metal Products, Inc. 187
Babson Bros. Co. 190
Bearings Co. of America Div., Federal-Mogul-Bower Bearings, Inc. 157
Blood Brothers Machine Div., Rockwell Spring & Axle Co. 155
Browning Mfg. Co. 195
J. I. Case Co. ..... 2nd cover
Chain Belt Co. 139
Clark Equipment Co. 153
Deere & Company 144, 145
Douglas Fir Plywood Assn. 201
Federal-Mogul Div., Federal-Mogul-Bower Bearings, Inc. 158
Hyatt Bearings Div., General Motors Corp. 146
Ingersoll Products Div., Borg-Warner Corp. 160
International Harvester Co. 151
Kaiser Aluminum & Chemical Sales, Inc. 156
Link-Belt Co. 143, 191
National Rain Bird Sales and Eng. Corp. 201
National Seal Div., Federal-Mogul-Bower Bearings, Inc. 142
Neapco Products, Inc. 199
New Departure, Div. of General Motors ..... 3rd cover
The Oliver Corp. 205
Pittsburgh Forgings Co. 204
Purolator Products, Inc. 141
Raybestos-Manhattan, Inc. Manhattan Rubber Div. 154
Rockford Clutch Div., Borg-Warner Corp. 192
Spraying Systems Co. 194
The Texas Company 152
Timken Roller Bearing Co. ..... 4th cover
The Torrington Co. 149
Warner Automotive Parts Div., Borg-Warner Corp. 150
West Coast Lumbermen's Assn. 193
Whitney Chain Co. 197
John Wiley & Sons 203
Wisconsin Motor Corp. 190
Young Radiator Co. 201

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about

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New Departure adapter ball bearings provide inexpensive mountings for many applications.

They are precision bearings, pre-lubricated and efficiently sealed. Also available with stamped flanges, these bearings become complete, initially aligned units for quick assembly.

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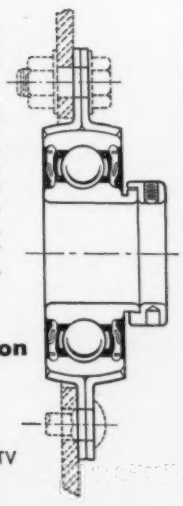
New Departure adapter bearings—Type AE—may be used to especial advantage on implements and machines operating at moderate speeds. Bearings with loosely assembled flanges are slipped on the shaft and lightly bolted to side plates. After flanges are finally secured, locking collars are tightened in the direction of rotation and fixed by set screw. Dimensions and load ratings of various adapter bearings are listed in the latest New Departure catalog.



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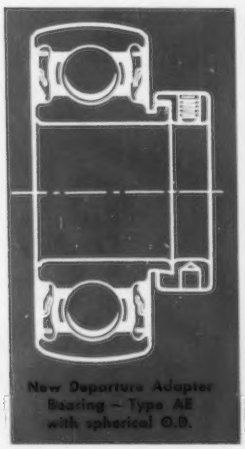
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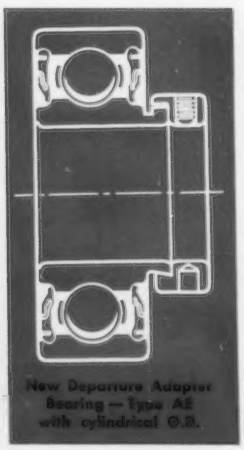
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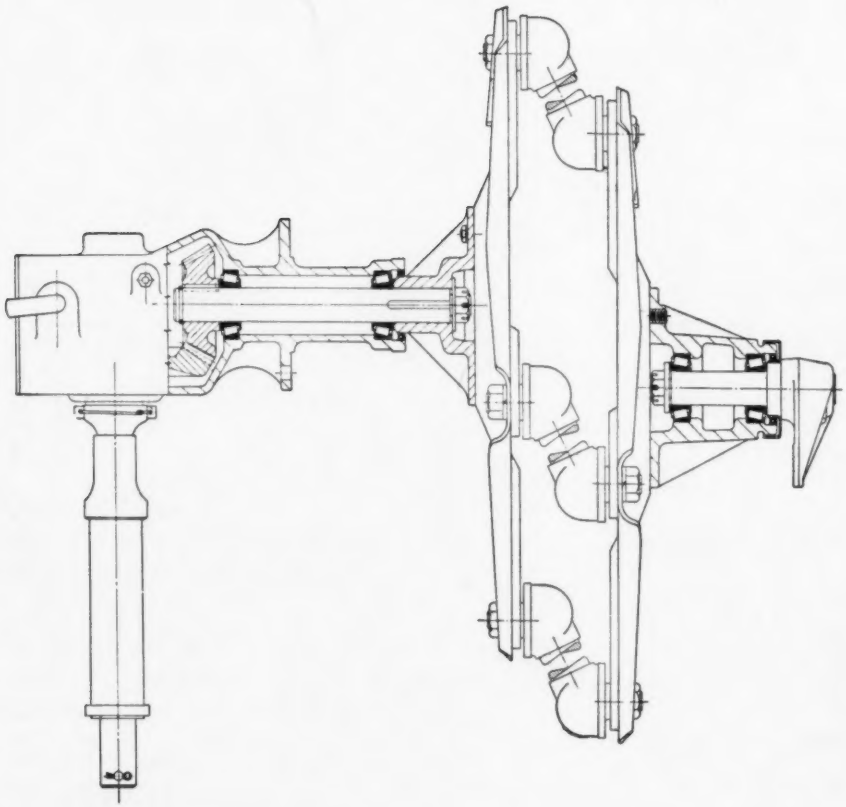
How New Holland cuts costs, gets accurate alignment, in hay rake reel



TO keep reel centers of their Model 55 Rolabar hay rake in accurate alignment under severe operating conditions, New Holland engineers mounted both ends of the reel shaft on Timken® tapered roller bearings. And by using popular high-production size Timken bearings, they also gained economical design.

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